



COLORADO
Department of Public
Health & Environment

Air Pollution Control Division

Technical Services Program

APPENDIX GM5

Standard Operating Procedure for the Determination of
Sulfur Dioxide in Ambient Air

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Standard Operating Procedure for the Determination of Sulfur Dioxide in Ambient Air

1 SCOPE AND APPLICABILITY

1.1 Introduction

This standard operating procedure (SOP) document describes the procedures used by members of the Air Pollution Control Division (APCD) Technical Services Program (TSP) to operate continuous monitoring sulfur dioxide (SO₂) analyzers at state of Colorado, Department of Public Health and Environment (CDPHE) air quality monitoring sites. This includes both standard and trace level analyzers at State and Local Air Monitoring Stations (SLAMS), special purpose monitoring (SPM) and NCore monitoring stations. The CDPHE uses the Teledyne Air Pollution Instruments (TAPI) 100A, 100E and T100U analyzers in its air monitoring network and this SOP covers all these analyzers. The TAPI T100U is a unique trace-level analyzer. These procedures are a supplement to APCD's Quality Assurance Project Plan (QAPP), the latest information published in the Code of Federal Regulations CFR), and the Operator's manual for TAPI 100A, 100E and T100U analyzers.

1.2 Method Overview

The method for the determination of sulfur dioxide (SO₂) has been widely used for almost 30 years. TAPI SO₂ analyzers, which operate on a ultra-violet (UV) fluorescence principle, initially attained federal equivalency designation in 1995, with new model designations in 2010 and 2013. The lower detection limit (LDL) for a standard sulfur dioxide analyzer (TAPI 100A and 100E) is 2 parts-per-billion (ppb) and for trace level analyzers (TAPI T100U) is 1 ppb (40 CFR 53.2). For reference, the primary sulfur dioxide standard is the 99th percentile of 1-hour daily maximum concentrations, averaged three years to not exceed 75 ppb (40 CFR 50.4). The secondary standard is the max daily 3-hour average, not to exceed 500 ppb more than once per year.

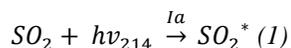
1.3 Format and Purpose

The sequence of topics covered in this SO₂ method follows 2007 EPA guidance on preparing standard operating procedures (SOPs). This method was also written to help field operators understand why (not just how) key procedures are performed. (US EPA, 2007)

2 SUMMARY OF METHOD

Operation of the SO₂ Analyzer is based upon proven technology from measurement of fluorescence of SO₂ due to absorption of UV energy. Sulfur Dioxide absorbs in the 190 – 230 nanometer (nm) region free of quenching by air and relatively free of other interferences. Interferences caused by poly-nuclear aromatics (PNA) are reduced by a "kicker" which removes PNA selectively through a membrane without affecting SO₂ sample gas.

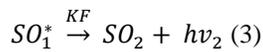
The UV lamp emits ultraviolet radiation, which passes through a 214 nm band-pass filter, excites SO₂ molecules, producing fluorescence, which is measured by a photo-multiplier tube (PMT) using a 330 nm UV band-pass filter. The equations describing the above reactions are as follows:



Where I_a is the average intensity of the UV light, hv_{214} is UV light at a 214 nm frequency, and SO_2^* is SO₂ at a higher energy orbital state. The excitation ultraviolet light at any point in the system is given by:

$$I_a = I_0 [1 - e^{-ax(SO_2)}] \quad (2)$$

Where I_0 is the UV light intensity, a is the absorption coefficient of SO₂, x the path length, and (SO_2) the concentration of SO₂. The excited SO₂ decays back to the ground state emitting a characteristic fluorescence:



K = the rate at which the SO₂* decays into SO₂

F = the amount of fluorescent light given off

When the SO₂ concentration is relatively low, the path length of exciting light is short, and the background is air, the above expression reduces to:

$$F = K(SO_2) \quad (4)$$

Hence, the fluorescent radiation impinging upon the PMT is directly proportional to the concentration of SO₂.

The PMT transfers the light energy into the electrical signal, which is directly proportional to the light energy in the sample stream being analyzed. The preamplifier board converts this signal into a voltage, which is further conditioned by the signal processing electronics. The UV light source is measured by a UV detector. Software calculates the ratio of the PMT output and the UV detector in order to compensate for variations in the UV light energy. Stray light is the background light produced with zero ppb SO₂. Once this background light is subtracted, the Central Processing Unit (CPU) will convert this electrical signal into the SO₂ concentration, which is directly proportional to the number of SO₂ molecules.

3 DEFINITIONS

The CDPHE/APCD/TSP QAPP contains an appendix of acronyms and definitions. Any commonly used shorthand designations for items such as the sponsoring organization, monitoring site, and the geographical area will be defined and included in this SOP or in the QAPP Appendix P2.

4 HEALTH AND SAFETY WARNINGS

Chemical Hazards: Purafil is used in the zero air generator to remove nitrogen oxide from air. Sodium permanganate is a component within Purafil and should be handled with care. Sodium permanganate is a known irritant and care should be taken to avoid exposure to open wounds, burns or mucous membranes. Prolonged exposure (usually over many years) to heavy concentrations of manganese oxides in the form of dust and fumes, may lead to chronic manganese poisoning, chiefly involving the central nervous system.

Compressed Gas Cylinder Hazards: Use and transport of SO₂ gas cylinders are a major concern. Gas cylinders may contain pressures as high as 2000 pounds per square inch. Handling of cylinders must be done in a safe manner. If a cylinder is accidentally toppled and the valve breaks off, the cylinder can become explosive or a projectile.

- Make sure the cylinder is equipped with the correct regulator, for SO₂ gas cylinders this is the stainless steel regulator with the Compressed Gas Association (CGA) 660 female connection. Do not use Teflon tape on threads connecting the regulator to the bottle. The regulator thread design allows for a tight seal and tape should never be used. Once the regulator is installed – provide a leak check using a proper leak check product.
- Inspect the regulator and cylinder valves for grease, oil, dirt, and solvent. Never use grease or oil to lubricate regulators or cylinder valves because they can cause an explosion.
- The cylinder should be placed so that the regulator valve handle is easily accessible.
- Only use wrenches or tools that are provided by the cylinder supplier to open or close a valve. Pliers should never be used to open a cylinder valve. Some regulators require washers; this should be checked before the regulator is fitted.
- Refer to MSDS for the gas being used for information regarding use and toxicity.

- Gas cylinders must be secured at all times to prevent toppling.
- Use appropriate material, such as chain, plastic coated wire cable, commercial straps, etc., to secure cylinders.
- Always place valve protectors on gas cylinders when the cylinders are not connected for use. Ensure that standing cylinders are strapped either to a transport cart or to a bottle rack, and NEVER standing while untethered.
- Cylinders must be protected from damage. Do not store cylinders near elevators or gangways, or in locations where heavy-moving objects may strike or fall on them.
- Cylinders must be stored where they are protected from the ground moisture to prevent rusting.
- Cylinders should be protected against tampering by unauthorized individuals.
- Sample and test gas should be delivered to the analyzer at atmospheric pressure. Ensure that the test gas is introduced to the sample stream through a tee where excess flow can be safely vented to the atmosphere.
- Do not completely empty the cylinder; always leave some residual pressure (200 psi).
- Transportation of cylinders is regulated by the Department of Transportation (DOT). It is strongly recommended that all agencies contact the DOT or Highway Patrol to learn the most recent regulations concerning transport of cylinders.
- Shipping of cylinders is governed by the DOT. Contact the DOT or your local courier about the proper procedures and materials needed to ship high pressure cylinders.

Electrical Hazards

1. Always use a third ground wire on all instruments.
2. If it is necessary to work inside an analyzer while it is in operation, use extreme caution to avoid contact with high voltage inside the analyzer. The analyzer has high voltages in certain parts of the circuitry, including a 110 volt AC power supply. Refer to the manufacturer's instruction manual and know the precise locations of these components before working on the instrument
3. Avoid electrical contact with jewelry. Remove rings, watches, bracelets, and necklaces to prevent electrical burns.
4. Always unplug the analyzer whenever possible when servicing or replacing parts.

5 CAUTIONS

To prevent damage to the equipment, the following precautions should be taken:

1. In the event that it is necessary to clean the optical bench, be careful to avoid damaging the interior of the sample chamber. Use extreme caution when cleaning or servicing the sample chamber(s).
2. Keep the interior of the analyzer clean. Be cautious while handling the analyzer. A drop could cause misalignment or damage to sensitive components.
3. Inspect the system regularly for structural integrity.

4. To prevent major problems with leaks, make sure that all sample and source/test gas lines are reconnected after required checks and before leaving the site.
5. Inspect tubing for cracks and leaks. Sample tubing and tubing within the analyzer may rest upon parts that vibrate, such as the air pump. Check the areas of the tubing where they come into contact with other parts for wear.
6. It is recommended that the analyzer be leak checked after replacement of pneumatic parts.
7. Ensure that all shelter electrical equipment is plugged into power strips and that the electrical load is properly balanced across the available circuits within the shelter.

6 INTERFERENCES

It should be noted that the UV fluorescence method for detecting SO₂ is subject to interference from a number of sources. The most common source of interference is from other gases that fluoresce in a similar fashion to SO₂ when exposed to UV Light such as Nitrogen Oxide (NO) and Poly-Nuclear Aromatics (PNA), and certain hydrocarbons, of which meta-xylene and naphthalene are the most pervasive. The TAPI 100 series analyzers have been successfully tested for their ability to reject interference from most of these sources.

7 PERSONNEL QUALIFICATIONS

General Personnel Qualifications are discussed in the CDPHE/APCD/TSP QAPP.

8 APPARATUS AND MATERIALS

8.1 Monitoring Equipment

8.1.1 Analyzers

8.1.1.1 TAPI 100E and 100A

“The 100E and 100A UV Fluorescence SO₂ Analyzer is a microprocessor controlled analyzer that determines the concentration of sulfur dioxide (SO₂), in a sample gas drawn through the instrument. It requires that sample and calibration gases be supplied at ambient atmospheric pressure in order to establish a constant gas flow through the sample chamber where the sample gas is exposed to ultraviolet light causing the SO₂ to become excited (SO₂*). As the SO₂* molecules decay back to their ground state, they fluoresce. The instrument measures the amount of fluorescence to determine the amount of SO₂ present in the sample gas.

Calibration of the instrument is performed in software and usually does not require physical adjustments to the instrument. During calibration, the microprocessor measures the sensor output signal when gases with known amounts of SO₂ at various concentrations are supplied and stores these measurements in memory. The microprocessor uses these calibration values along with other performance parameters such as the PMT dark offset, UV lamp ratio and the amount of stray light present and measurements of the temperature and pressure of the sample gas to compute the final SO₂ concentration. The TAPI 100E does not have the capability to perform automatic baseline adjustments to compensate for zero drift; therefore the APCD may elect to perform post processing data adjustments to account for a drifting baseline.

This concentration value and the original information from which it was calculated are stored in the unit’s internal data acquisition system and reported to the user through a vacuum fluorescent display or as electronic data via several communication ports. This concentration value and the original information from which it was calculated are stored in the unit’s internal data acquisition system and reported to the user through a vacuum fluorescent display or several communication ports.”(Teledyne-API, 2009)(Teledyne-API, 2013)

8.1.1.2 TAPI T100U (Trace)

“The TAPI T100U analyzer operates on the same principle as the above described TAPI 100E analyzer with several notable exceptions. The primary differences are the way in which the PMT and UV reference signals are acquired and processed. The T100U has no shutter but rather employs synchronous demodulation to capture the dark and light PMT and UV reference signals several times per second. A printed circuit board includes circuitry that digitizes the PMT and UV reference signals and synchronizes the operation of the UV source with these measurements. This method of signal processing minimizes the error that changing offsets could make in an instrument that is designed to operate near its detection limit. Additionally, the T-series designation refers to an upgraded operating system that includes native Ethernet communications, touch screen interface, and expanded internal data acquisition system capabilities.”(Teledyne-API, 2011)(Teledyne-API, 2011)

8.1.2 Instrument Shelter

A shelter is required to protect the analyzer from precipitation and adverse weather conditions, maintain operating temperature, and provide security and electrical power. The following are operational shelter temperature requirements for the SLAMS (US EPA, 2013) and NCore networks (US EPA, 2005).

SLAMs: 5-40 °C (20-30 °C preferred) at $\leq \pm 2$ °C Standard Deviation over 24 hours.

SLAMs: 41-104 °F (68-86 °F preferred) at $\leq \pm 3.6$ °F Standard Deviation over 24 hours

NCore: 20-30 °C, daily changes in hourly temperature should not exceed ± 5 °C over a 24-hour period.

NCore: 68-86 °F, daily changes in hourly temperature should not exceed ± 9 °F over a 24-hour period.

8.1.3 Test Gas System

The APCD uses a Teledyne Advanced Pollution Instrumentation (TAPI) Model 700 dynamic dilution calibration system to create concentrations of SO₂ by diluting the contents of a National Institute of Standards and Technology (NIST) traceable compressed gas cylinder. For details on the operation of the calibration system, refer to the API Operator’s Manual and to the SOP “*Standards Verification and Calibration Standard Operating Procedure*” in the Air Pollution Control Division (APCD) Quality Assurance Project Plan (QAPP.) The compressed gas cylinders at the site are multi-blend mixture of the target analytes with a nitrogen base. The zero air at the site is produced by pumping room air through a TAPI model 701 zero air module. For removal of interferences, the air is also passed through a Purafil/charcoal scrubber system. All gas must be delivered to the instrument at atmospheric pressure.

This system is enhanced by the use of the station data logger to control the span and precision process and data collection in the same manner if performed on site, remotely, or automatically. This standardizes the test process and reduces process errors. Data logger control of tests and data averaging allows test results to be reported by the data logger to a central computer. To provide the desired span/precision concentration, pre-programmed sequences are stored in the dynamic dilution calibrator. These sequences are subsequently triggered by the station’s data logger through a series of contact closures or by the activation of modbus coils. The test gas system generates 80-100 ppb for the span level and 18 – 25 ppb for the precision level.

8.1.4 Data Acquisition System

The APCD employs three different models of onsite, data acquisition system equipment (DAS) in the operations of its air monitoring network. These are the ESC 8816 data logger, the ESC 8832 data logger, and the Agilaire 8872 data logger. The 8816 model is the oldest type of data logger in the network and is a predecessor to the 8832 and 8872 data loggers. The following are descriptions of these data loggers.

ESC 8816 Data Logger

The ESC Model 8816 Data System Controller is a microprocessor-based data acquisition system designed to acquire, process, store, report, and telemeter data in a multi-tasking environment. The 8816 is designed around an expansion bus that gives the user great flexibility in configuring the unit with a combination of analog and serial input and output (I/O) types. (Environmental Systems Corporation, 2001)

For more details, refer to APCD's Data logger SOP or the individual operator manuals.

ESC 8832 Data Logger

The ESC Model 8832 Data System Controller is a microprocessor-based data acquisition system designed to acquire, process, store, report, and telemeter data in a multi-tasking environment. The 8832 is designed around an expansion bus that gives the user great flexibility in configuring the unit with almost any combination of input and output types. It is the successor to the 8816 data logger and is more robust in numerous areas. Of significance is expanded memory, faster processing speeds, faster communication speeds, remote Ethernet communications and polling and Modbus enabled communications with peripheral devices. (Environmental Systems Corporation, 2006)

For more details, refer to APCD's Data logger SOP or the individual operator manuals.

Agilaire 8872 Data Logger

The Model 8872 is a Windows-based data logger, a departure from the earlier 8816 / 8832 embedded systems designs. The 8872 includes a number of hardware and software features to ensure that the device matches the field reliability of the 8832, while offering the convenience of a Windows-based platform and integration with Agilaire's AirVision software.

The core of the 8872 is a fan-less PC, with typically 2 GB of RAM. The device can be equipped with a 160 GB standard hard drive or, more commonly, a 64 GB solid state flash drive (SSD). For all digital versions of the 8872, the remainder of the enclosure simply provides convenient universal serial bus (USB), serial, and VGA I/O connections in a standard 3U rack mount enclosure, a form factor similar to the 8816 / 8832 family. However, the 8872 also supports traditional analog/discrete I/O via a variety of internal I/O modules and a protection / connector board to provide familiar detachable terminal block connections to the back. The layout of the connections is designed to make the unit easy to use as a 'drop in' replacement for an 8816 or 8832. (Agilaire, 2013)

For more details, refer to APCD's Data logger SOP or the individual operator manuals.

8.1.5 Wiring, Tubing and Fittings

Teflon™ and borosilicate glass are inert materials that should be used exclusively throughout the ambient air intake system. It is recommended that Polytetrafluoroethylene (PTFE) or Fluoroethylpropylene (FEP) Teflon™ tubing and fittings be used. FEP Teflon is the best choice for sample lines and the connection between an intake manifold and the bulkhead fitting because of its inertness and lower costs. All fittings and ferrules should be made of Teflon™. Connection wiring to the DAS should be shielded two-strand wire for analog communications and properly shielded RS-232 serial cable or Cat5 or higher Ethernet cable for digital communications.

8.1.6 Reagents and Standards

A reagent is a substance or compound used to bring about a chemical reaction. The TAPI 100A/E/U analyzer does not require reagents since it uses photometry to analyze for SO₂. All gas calibration and QC precision test gas concentrations for the SO₂ method are obtained by the dynamic dilution of gas from cylinders whose contents are traceable to National Institute of Standards and Technology (NIST) Standard Reference Material (SRM) gases via Environmental Protection Agency (EPA) Protocol procedures.

8.1.7 Spare Parts and Incidental Supplies

Teledyne 100E and 100A: See Chapter 10 (Preventive Maintenance), Chapter 12 (Troubleshooting) and Appendix B (Spare Parts) in the Teledyne “Model 100E UV Fluorescence SO₂ Analyzer, P/N 04515” for specific maintenance and replacement requirements.

Teledyne T100U: See Chapter 9 (Preventive Maintenance) and Chapter 11 (Troubleshooting and Repair) in the Teledyne “Addendum to Model 100E Operators Manual for Model EU Trace Level Sulfur Dioxide Analyzer, P/N 04515” for specific maintenance and replacement requirements.

8.2 Calibration Equipment

8.2.1 Calibration System

See Figure 1.

- Dilution gas calibrator.
 - The calibrator must have mass flow controllers for dilution air with flow from 0.0 – 10.0 liters per minute (Lpm) and SO₂ cal gas at 0.0 – 100 ml/min, with these flows as the minimum full scale ranges (Mesa Laboratories, MK01-26 Rev H).
 - The calibrator must have a mixing chamber for dilution air and calibration gas flows.
 - Replaceable outlet particulate filter.
 - High volume/pressure air pump.
 - Permeation dryer, Indicating Silica gel or Calcium Carbonate.

8.2.2 Accessories and Incidental Supplies

- External flow meter system capable of measuring flows of 10 - 10000 cc/min with < +/- 1% accuracy.
 - All flow measurement systems are to be certified by the manufacturers against references traceable to an NIST standard.
- Digital thermometer measuring to tenths of a degree Celsius. It is periodically referenced against an in-house mercury thermometer that is traceable by the manufacturer to a NIST standard.
- Hand held barometer measuring to the tenths of an inch Hg. It is periodically adjusted against the in-house digital barometer standard that is traceable by the manufacturer to a NIST standard.
- Digital voltmeter (DVM) with a 0 - 1 volt range. It is periodically referenced against the in-house voltage standard, which has NIST traceability.
- Connecting lines made of 1/4" OD Teflon.
- Teflon™ is an inert material that should be used exclusively throughout the calibration system. It is recommended that Polytetrafluoroethylene (PTFE), Fluoroethylpropylene (FEP) Teflon™ or Perfluoroalkoxy (PFA) tubing be used. They are all equally effective, however (FEP) Teflon™ is the most cost effective solution.
- Calibration sheet (Figure 3).

8.2.3 Reagents and Standards

Certified SO₂ calibration gas cylinder bottle are traceable to a NIST standard via EPA Protocol 2. Pre-dilution concentrations used are usually approximately 10 to 50 ppm in a balance of nitrogen.

9 CALIBRATION

9.1 Introduction and Summary

The calibration of a gaseous analyzer centers on introducing known concentrations of a pollutant to the analyzer and adjusting the analyzer so that its readings accurately represent those concentrations (US EPA, 2013). An overview of the calibration process is given below.

1. Site Inspection (section 9.2):
 - a. General inspection of the station shelter.
 - b. General inspection of all measurement and recording instruments, along with the SO₂ analyzer, to see if they are working properly.
 - c. Minor maintenance on the shelter or instruments if required and within the scope of the cal worker's resources. If any of the analyzer operational parameters are out of specification or nearing being out of specification from the station log sheet target values, the calibration should be halted so repairs and/or major maintenance can be performed prior to calibration.
2. Calibration Procedure (section 9.3):
 - a. A pre-calibration auto span and precision routine is run (section 9.3.2).
 - b. A pre-calibration audit point at the precision level using the calibration equipment is introduced, plus calibration zero, to the SO₂ analyzer (section 9.3.3.1, Pre-Calibration Audit Procedure).
 - c. Performance of any minor maintenance on the analyzer if required and within the scope of the calibration specialist's resources. If major repairs are needed, the calibration should be halted so that this can be done before any calibration.
 - d. Adjustment of the analyzer's responses so that they accurately reflect introduced known concentrations of SO₂ (section 9.3.3.2, Calibration Adjustment) .
 - e. Introduction of five SO₂ concentrations plus zero air in order to characterize the calibrated SO₂ analyzer's response curve (section 9.3.3.3, Post-Calibration Assessment).
 - f. Determination of the automated zero, span, and precision values (section 9.3.3.3, in Post-Calibration Assessment).
3. Calculation, recording, and reporting of results. A detailed description of this procedure is presented below in Sections **Error! Reference source not found.** and 9.4

9.2 Site Inspection

A site inspection is conducted every time a calibration specialist goes to a monitoring station to calibrate, audit, or perform any other kind of GMM unit operation.

The inspection routine includes the following actions:

1. Check that any water drop (if present), and sample lines are not dirty or show condensation.
2. Check that all monitors' operational parameters such as pressure, temperature, and sample flow look normal compared to the values recorded on their calibration stickers and station log sheets. Refer to an analyzer's manual and station SO₂ log sheet for allowable ranges for each of its diagnostic parameters. If any parameter on any analyzer is out of bounds then the monitoring technician should be notified that day. Maintenance should be performed by the calibration specialist if possible, and a calibration on the analyzer may be necessary afterwards.
3. Check that the station temperature high/low readings are within a range of 20 - 30 °C (68-86°F).
4. Check the station logs for non-routine actions.
5. Check that all gaseous analyzers and meteorological (met) sensors appear to be reading ambient values that are reasonable given outside conditions and past readings for that individual station. This is done by looking at the real time data logger readings. For the gaseous analyzers, make sure their front panel readings match those on the data logger. For specifics on using the data logger refer to data logger SOP appendix in this QAPP document.
6. If you need to access the data logger functions through one or more login codes (codes are required) and aren't sure if you're authorized for access, call either the supervisor or the monitoring technician to see if you are. If you know that you are authorized, but have forgotten the login codes, call key contact personnel within the GMM unit for the codes. Key contact people within the GMM unit are posted within every monitoring station.
7. If present, visually check that the meteorological tower's instrument crossbar is properly aligned. Check that the meteorological sensors aren't damaged and are moving without binding.
8. Check that the station structure is not damaged.
9. Check that all analyzer clocks and digital chart recorder clocks agree with the data logger and that they are showing the proper time (10.6.7). If any change is made to a device then log the action, date and calibration specialist's initials in the relevant log. For changes to the data logger clock consult first with GMM supervisory or data management staff.
10. Check that all pumps are running smoothly and are not overly hot to the touch. Check also that exhaust lines between the pump and the analyzer are not rubbing on the pump, which can lead to a hole being worn in the line.
11. Perform a leak check on the analyzer that is to be calibrated (10.6.6).

If anything is found out of the ordinary it is to be recorded in the relevant log, along with the date and the calibration specialist's initials. The station's monitoring technician is notified that day (or another monitoring technician of the GMM unit if that person is not available). Maintenance should be performed if appropriate and within the scope of the calibration specialist's resources.

9.3 Calibration Procedure

9.3.1 Calibration Train Setup

1. Connect the clean air supply directly to the zero air input of the calibrator (Figure 1).

2. Before the SO₂ cal gas cylinder is connected to the calibrator, its line and regulator must be purged at least three times. This is done in order to remove all ambient air from the regulator. (Ambient air in the regulator can dilute the SO₂ and bias the calibration results and introduce ambient contaminants that interact with the SO₂.) The following describes the line and regulator purging action:
 - a. Open the regulator and cylinder valves. The closed quick connect will keep the cal gas from escaping
 - b. Close the cylinder valve.
 - c. Push the end of the quick connect nozzle against a clean, flat surface to partially release the pressure within the regulator and line. Carefully watch the two regulator gauges and do not let either of them fall to zero. A positive pressure compared to ambient must be kept so that room air will not surge back into the line and regulator. To stop the release of cal gas, pull the quick connect nozzle away from the flat surface.
 - d. Repeat Steps a through c two times.
 - e. Open the cylinder valve to recharge the regulator and line to full pressure as indicated by the two regulator gauges.
3. After purging, connect the SO₂ cal gas regulator line directly to the cal gas input of the dilution calibrator. Adjust delivery pressure between 20 to 30 psi.
4. Connect a Teflon line to the exit port of the transfer standard calibrator. The length of this line should be of sufficient length to reach from the transfer standard (TS) calibrator to the back of the station (Stat) calibrator or the station analyzer. This is the transfer standard calibrator supply line (supply line). Leave this other end of this line unconnected end for now.
5. The introduction of test gas to the analyzer can be performed in one of two ways depending upon how the station calibrator is configured for the nightly performance tests. The transfer standard calibrator should be configured similarly to the station calibrator if possible. If the station calibrator is configured to introduce test gas through the probe (TTP) then the transfer standard calibrator should be configured likewise. The same is true if the station calibrator is configured to the back of the analyzer (BOA). In most situations the site calibration line can be removed directly from the back of the station calibrator and connected to the transfer standard calibrator output line with a Teflon union. If the a solenoid manifold is used external to the station calibrator to direct test gas TTP to individual analyzers, then it is acceptable to connect the transfer standard output line to the station TTP calibration line on the output side of the solenoid. Simply disconnect the TTP calibration line from the output side of the solenoid and connect it to the transfer standard output with a Teflon union. This method eliminates the need to activate the solenoid for the entire length of the calibration. An exception to the above methods is if the station calibrator is connected directly to a calibration port on the back of the analyzer. In this situation the sample line is removed from the sample inlet port on the back of the analyzer and the transfer standard output line is connected directly to the sample inlet port through the use of a Teflon tee. A 12" (or >) length of clean Teflon is connected to the empty leg of the tee that will be used as a vent to bleed off excess test gas that is introduced to the analyzer by the transfer standard calibrator to prevent back pressure in the analyzer.

9.3.2 Pre-calibration Zero, Span, and Precision Routine

This routine is done before there is adjustment to the analyzer to help correlate the preceding automatic zeros and spans (z/s) and precisions (p) with the pre-calibration audit responses. It is also done at the end of the calibration procedure to generate new official z/s/p values for the following sampling period until the next calibration. In practice these routines are started just before and after any calibration / audit to allow time to set up or tear down the calibration equipment while they run their course.

If the analyzer is communicating with the data logger over an analog connection, connect a digital volt meter (DVM) or digital chart recorder to the analog output of the monitor or the analog input of the data logger according to ease of accessibility. This step should not be performed if the analyzer is communicating with the data logger over a digital connection (GSI or Modbus). Readings on the data logger are taken from the SO₂ channel (and not, e.g., the SO₂ MAX channel).

1. Take the SO₂ analyzer offline (10.6.1).
2. Start an automatic precision/zero routine. This is done by a command through the data logger (10.6.10). Allow this routine to run fully until its automatic ending. During the run make sure that all readings from the front panels of the station calibrator and SO₂ analyzer match the numbers seen in the data logger. Record the final reported numbers on the cal sheet. A precision is done before a span because the SO₂ analyzer is more sensitive to conditioning effects at this level, and the purpose of the pre-cal precision is to emulate the midnight precisions as closely as possible.
3. Start an automatic span/zero routine as done in the above Step2 with the precision. If a second auto zero is not needed, the automatic span/zero routine can be aborted through the data logger after the span part of the cycle is finished; but if done so, the last five minute readings of the station calibrator and analyzer during span must be manually averaged as no report will be provided by the data logger.
4. Zero-correct the data logger precision and span test levels (t) results.

Equation 1. Zero Corrected Test

$$t - \text{zero value} = \text{zero corrected test level (zct)}$$

5. Calculate the percentage relative error (%RE) of the two zcts and record on the calibration sheet.

Equation 2. Percent Relative Error

$$\frac{zct - \text{Actual Concentration} *}{\text{Actual Concentration} *} * 100\% = \%RE$$

*Actual Concentration is the concentration of the test gas as reported by the station calibrator system through the data logger

The pre-calibration span and precision plus station zero can also be run manually through the data logger, but the calibration specialist must be careful to emulate automatic phase times so that conditioning effect differences between previous midnight auto spans and precisions and this pre-calibration span and precision can be minimized. For some diagnostic purposes a manual running of the precision and span is sometimes more useful and practical than using the automatic routines. The manually triggering of relays through the data logger is non-routine and the procedure to perform this task is not included in this SOP. Contact the Data Manager to attain information on how to perform this task.

9.3.3 Pre-Calibration Audit, Calibration Adjustment and Post-Calibration Assessment

9.3.3.1 Pre-Calibration Audit Procedure

Introduction

From the transfer standard calibrator set up introduce zero and precision levels test gas to the analyzer. Calculate %RE for the zero corrected precision level results. If this exceeds +/- 10.1 %RE, follow with a full five point plus zero calibration assessment audit (the same as a post-calibration assessment in method below) before any adjustment is made to the analyzer. This assessment audit is the same as described below in section 9.3.3.3 Post-Calibration Assessment. These subsequent assessment levels are used to characterize the out-of-spec condition fully, and the

information will be used during data validation. Failed pre-calibration assessment audits require an electronic message in the data logger that will to be use for data validation purposes.

If the analyzer fails the pre-calibration assessment audit then repairs and calibration of the instrument are done as soon as possible after the audit. If the repairs required are beyond the resources of the calibration specialist then the monitoring technician for that station is notified immediately. Proceed to the calibration adjustment procedure in Section 9.3.3.2 if the pre-calibration audit results less than +/- 10.1 %RE. The procedure for performing the pre-calibration assessment is given below.

Procedure

1. Generate a zero point (Level 5) from the TS calibrator. If a TAPI 700x calibrator with certified MFCs is used then simply request the desired SO₂ concentration level or ZERO point. Refer to the calibrator's operating manual for procedures on how to generate manual concentrations from the calibrator (Teledyne-API, 2009). Make sure the correct port and SO₂ tank concentration are programmed into the calibrator.
2. Let the dilution airflow in the calibrator stabilize. This should usually take less than five minutes.
3. Connect the transfer standard calibrator to the analyzer's inlet system. This connection can be made several ways depending upon how the station calibrator is configured with the inlet system. Please see Section 9.3.1 Step 5 for a more detailed description of the setup options.
4. Send zero air through the probe to the analyzer from the TS calibrator. Be sure that excess supply flow at the probe is 10 to 50% greater than analyzer flow (compare total flows of analyzer and TS calibrator).
5. Allow at least five minutes after the analyzer has stabilized. Record the results on the calibration sheet. This is the pre-calibration zero air concentration reading.
6. Generate a test SO₂ flow that will cause a 10 to 20 % full scale of reading (the precision level). The MFCs in the TS calibrator should not be used below 10% or above 90% of their full scale for older TAPI 700xs. Some of the newer MFCs in newer TAPI 700xs are capable of using an upper range of 99% of their full scale, but if in doubt use the more restrictive range when generating a concentration while keeping in mind that an excess of gas must be provided to the probe.
7. Allow at least five minutes after a stable response from the analyzer is achieved. Record the results on the calibration sheet. Zero correct the results. Note: at lower SO₂ concentrations equilibration time may be long; it is important that the analyzers response is allowed to plateau.

Calculate the relative error of the analyzer's response

Equation 3. Percent Relative Error

$$\frac{\text{Analyzer Reading} / (\text{DAS}) - \text{true}[\text{SO}_2]}{\text{true}[\text{SO}_2]} * 100\% = \%RE$$

8. If the precision level error is < +/- 10.1% RE a full assessment audit is not required, proceed to 9.3.3.2. If it exceeds +/- 10.1 %RE, the pre-calibration assessment fails, follow with a full four point plus zero calibration assessment audit (the same as a post-calibration assessment in section 9.3.3.3 below) before any adjustment or repairs are made to the analyzer. This is to characterize the out-of-spec condition fully, and the information will be used during data validation. Additionally, if the assessment fails, documentation of this failure in a Message to Central is required as described in Section 9.3.3.3 Step 10.

9.3.3.2 Calibration Adjustment

Introduction

After the pre-calibration audit, the analyzer is adjusted (calibrated) at the zero and precision levels so that the analyzer most closely matches the known concentrations produced by the calibration system at the zero and precision levels. After this is done, a five level plus zero multipoint post-calibration assessment (Section 9.3.3.3) is reintroduced to characterize the analyzer response over the entire measurement range. The calibration points are generated by diluting a higher concentration of SO₂ from a NIST-traceable calibration gas to a target concentration. The recommended ranges for the multi-point calibration points are detailed in Table 1. As each calibration point is generated, the responses shown by the data logger should be compared to the calculated value.

Table 1. Calibration Ranges for Sulfur Dioxide Analyzers

| SO₂ Calibration Ranges | |
|--|-------------------------|
| Units | Parts per billion (ppb) |
| Full scale range | 0 to 200 ppb |
| Compressed gas cylinder | 10-20 ppm* |
| * Based on calibrator mfc ranges: gas1 = 50ml/min, gas2 = 100 ml/min, dil = 10 or 20 l/min | |
| Calibration points | |
| Level 1 | 150-200 ppb |
| Level 2 | 100–150 ppb |
| Level 3 | 50–100 ppb |
| Level 4 | 10–50 ppb |
| Level 5 - zero | 0-0.1 ppb |

Level 4 is the accepted precision level that is used to adjust the calibration of the analyzer with as little error as possible (along with Level 5, or the zero level). The procedure for performing the calibration adjustment is given below.

Procedure

1. To start the analyzer calibration adjustment (if needed), introduce zero air again to the analyzer and let the analyzer stabilize.
2. TAPI 100E/EU: Press CAL. ZERO will appear. Press this. Display concentration will go to 0.000.
3. Generate the precision level SO₂ concentration and direct it to the analyzer. The concentration generated by the TS calibrator is referred to as the “true” concentration. Let the analyzer stabilize.
4. TAPI 100E/EU: Press CAL. CONC will appear. Press this. SO₂ SPAN CONC: XXX.X CONC will appear. Using the corresponding buttons under the digits, input the true precision level concentration. Press ENTER
5. TAPI 100E and TAPI 100A: To auto calibrate analog outputs go to DIAG menu, then ANALOG I/O CONFIGURATION. Press ENTER. On AOUTS CALIBRATED menu, press ENTER. A YES

signal will show auto calibration completed. To adjust analog output offsets, from ANALOG I/O CONFIGURATION menu, press ENTER.

6. TAPI 100E and TAPI 100A: Press SET until CONC_OUT_X:1V, CAL (where X=output channel under adjustment) appears. Press EDIT. Press SET until CONC_OUT_X REC OFS:0 mV appears. Press EDIT and then enter channel offset value in mV. Adjust the offset until the data logger reading matches the front panel display of the analyzer.
7. **This and all following steps in section 9 apply equally to all TAPI 100 versions.** Steps 1 thru 6 can be repeated if the calibration settings from the initial calibration or subsequent calibrations are not sufficiently accurate. This is accomplished by independently sending zero air and known test gas concentrations (10 to 20% of calibration full scale) to the analyzer to assess the accuracy of the calibration. If the results are not optimal, repeat steps 1 thru 6. Several jumps between the zero air and the test gas, along with calibration adjustments, may be required. Record the calibration results on the calibration sheet.

9.3.3.3 Post-Calibration Assessment

Introduction

The post-calibration assessment challenges the analyzer with five different test gas concentrations levels plus a zero to evaluate the accuracy of the new calibration. The assessment begins with a zero point followed by points at <20% (Level 4 - precision), >80% (Level 1 - span), ~60% (Level 2), and ~40% (Level 3). Results for these tests are used to evaluate the relative error at full scale. Concentration levels are generated as described in the pre-calibration assessment (**Error! Reference source not found.**). The procedure for performing the post-calibration assessment is given below.

Procedure:

1. Send precision level gas to the analyzer. Let it stabilize for at least five minutes. Record the results on the calibration sheet.
2. Introduce a Level 1 concentration (greater than 80% full scale to the analyzer). Let it stabilize for at least five minutes. Record results on the calibration sheet.
3. Measure and generate three more SO₂ concentrations that come in at approximately 70, 50, and 30% of full range. Introduce to the analyzer as above. Record the results on the calibration sheet.
4. Send a final zero air to the analyzer and record the results. Calculate a least-squares linear regression between the known SO₂ concentrations (including the zero point) as the ordinate and the zero corrected analyzer responses as the abscissa. Record slope, intercept, and correlation coefficient on the calibration sheet. Also calculate, using this response curve, a % REFS (Equation 6) for a calibrated analyzer response given a known introduced concentration of exactly 90% of the full measurement range of the analyzer.
5. The criteria for a successful calibration is where all non-zero test points after the calibration adjustment show a <+/-2% full scale error from the final best fit regression calibration line. The precision level should be as close to 0% error as possible. If the post-calibration assessment begins to show a failure at any point, and repeating previous analyzer adjustments do not solve the problem, then maintenance is probably needed for the analyzer.

Equation 4. Relative Error at Full Scale

$$\frac{[(90\% \text{ full scale} * m) + i] - 90\% \text{ full scale}}{90\% \text{ full scale}} * 100 = \%REFS$$

where:

m = slope of response curve.

i = intercept of response curve.

90% full scale = 180 ppb (calibration scale 0-200ppb).

%REFS = Relative Error at Full Scale

6. Reattach the station calibrator's supply line back to its solenoid valve on the span panel.
7. Do another zero, span and precision routine as performed in Section 9.3.2. Record results on the calibration sheet and on the calibration sticker.
8. Record analyzer parameters, especially the new analyzer calibration settings (slope, offset), from the front panel display on the calibration sticker and sheet.
9. Enable the analyzer (10.6.1). Record the MST time the instrument was brought back on line on the calibration sheet and on the station SO₂ log. Put the calibration sticker on a surface near the analyzer so that it is easily read.
10. Enter the calibration results in a "message to central" (10.6.8). On the data logger message window to Central type and send:

C:SO₂, Z=aaa, S=bbb, P=ccc , ddd <enter> where:

aaa = data logger SO₂ zero reading in ppm.

bbb = data logger SO₂ uncorrected span reading in ppm.

ccc = data logger SO₂ uncorrected precision reading in ppm.

ddd = calibration specialist's initials.

This is a message through the data logger to the GMM unit worker responsible for tracking calibrations in the ZSPTracking database. This message is permanently stored in the AirVision system and information from this message is manually inputted into the ZSPTracking database.

In the event of a failed precalibration audit or assessment, a separate message is sent to Central in the form of

SO₂ CAL FAILED AUDIT,

(in all CAPS) followed by a general description in regular text and the calibrator's initials. This is to highlight important cal/audit information for the purposes of data validation.

11. Record analyzer parameters and calibration and maintenance actions on the station SO₂ log.

9.4 Reporting and Filing of Calibration Results

The results of a calibration or assessment audit are recorded and reported by the calibration specialist as follows (this is a summary; some of these actions have already been mentioned):

1. Record analyzer parameters, calibration and maintenance actions, cal date, beginning/ending disabled time and calibration specialist's initials on the station logs.

2. Record the calibration and audit points, linear regression results, cal date and calibration specialist's initials on the calibration report form (Figure 4) and in the Calibrations database (Figure 4), on their field PC, along with relevant comments. If possible and if the required computer and software are available, download the data stored in the analyzer's own internal data logger.
3. Any unusual thing seen at a station, even if rectified by the calibration specialist, is reported that day to the monitoring technician and recorded in the station logs.
4. Record uncorrected data logger and chart z/s/p results, analyzer calibration settings, cal date and calibration specialist's initials on the station sticker.
5. File data logger z/s/p results into the data logger (see Section 9.3, Step 10 above). These can be accessed at any time by the home office.
6. Put the calibration sheet with all of the calibration information, beginning/ending disabled time, cal date and calibration specialist's initials into the specially designated ring binder at the home office. Each year of calibrations and assessment audits has its own binder. The most recent four to five years of calibration and audit sheets are kept at the home office. Older binders are put into permanent storage.
7. When the calibration specialist is at the home office, the Calibrations database forms on their field PCs will be uploaded to the Technical Services' J:Drive Master Calibration database on a monthly or less than monthly basis.

10 OPERATION AND MAINTENANCE

10.1 Introduction and Description of Monitoring

The APCD Technical Support Program (TSP) uses exclusively TAPI model 100A, 100E and T100U sulfur dioxide instruments. In 2000 the TSP began replacement of its older technology TECO Model 43A ambient SO₂ analyzers with newer TAPI 100 instruments. In 2012, the TSP began using TAPI T100U trace level instruments in new sites, including Denver's NCore site. Some factors influencing the installation of trace level analyzers are:

- federal requirements to use trace level instrumentation at NCore monitoring sites
- diminishing ambient concentrations require the use of trace level analyzers to achieve higher accuracies at lower concentrations

Two manuals give the operational details and requirements for the two systems. The TAPI 100E and the TAPI 100EU addendum, to the 100E manufacturer's instruction manual, are complete and cover all necessary procedures and controls for successful operation (Teledyne-API, 2013) (Teledyne-API, 2011) (Teledyne-API, 2011) (Teledyne-API, 2009). These manuals are available at each SO₂ site, with each manual accompanying its respective analyzer, and at the central offices of TSP. For the ESC AQM-8816, AQM-8832 and Agilaire 8872 data loggers, the manufacturer's technical manuals provide all operating instructions and system keyboard command descriptions. These manuals are also available at each site, with each manual accompanying its respective analyzer, and at the central offices of TSP. Refer to these manuals regarding any aspect of operation of these systems (Environmental Systems Corporation, 2001) (Environmental Systems Corporation, 2006) (Agilaire, 2013).

Each continuous SO₂ monitoring site is assigned to a specific TSP employee qualified by formal training, experience, TSP on-the-job training, and courses offered by EPA. This employee is responsible for all aspects of assigned site monitoring operations, including but not limited to maintenance, repair, documentation updates, logs, etc. In addition to keeping sites operational with minimal downtime, any of the senior level instrument specialists may be called upon to accept the responsibility for training of new TSP employees and contracted operators.

In the current monitoring network all of the gaseous analyzers have some capacity to store data through an internal Data Acquisition System (iDAS). iDAS provides a backup of data by storing it on the analyzers internal memory. As a result TSP considers the data acquired by the site data logger system, when properly validated, to be the primary data source and iDAS data as an emergency data backup system. The iDAS system can also be use as a troubleshooting tool if properly configured.

Data quality and validity determinations are based partly on quality control (QC) data produced from onsite test systems. An “Onsite Test System” is a system of control hardware, software and standards at the monitoring location that is capable of accurately generating and introducing known concentrations of test gas to a monitoring system. These onsite test systems are capable of performing “Performance Tests” and “QC Precision Tests”. The different tests are used to assess and document different aspects of system performance and data quality. A “Performance Test” is an automated or manual evaluation of a monitoring system’s performance and is achieved through the introduction of a known concentration of test gas, typically at the span or precision level, and is not intended to be submitted to EPA for determinations of bias. A “QC Precision Test” is a manual check initiated by APCD staff, who can attest to its validity, and is achieved through the introduction of a known concentration of test gas at the precision level and whose purpose is to be submitted to EPA for determination of bias. “Performance Tests” and “QC Precision Tests” are inherently different and are initiated by different sequences within the data logger. These sequences consist of phases that can vary in concentration, order, and duration.

For SO₂, test concentrations are listed below.

Table 2. SO₂ Test Targets

| | Span | Precision |
|-----------------------------|-------------|------------------|
| Diluted EPA protocol | ~80 ppb | ~20 ppb |

The APCD uses a dynamic dilution EPA protocol test gas system in the sulfur dioxide air monitoring network. The explanation of this onsite test system is as follows.

Diluted EPA protocol test gas system

The test gas and a zero-air source are connected to a dynamic dilution calibrator, which then connects to the analyzer sample inlet system. The onsite test system that introduces known test gas concentrations to select SO₂ analyzers does so by blending known concentrations of test gases with diluent air having zero concentration of the test analyte. A bottle of high concentration test gas and a source of diluent gas are connected to a TAPI model 700 dilution calibrator containing two or more calibrated mass flow controllers. The dilution calibrator is then instructed to generate concentrations which are fed to a solenoid manifold configured to allow the gas to the sample inlet of the analyzer at atmospheric pressure.

The combination of the NIST traceable test gas and the calibrated mass flow controllers provide sufficient confidence in the calculated concentrations. This system is ideal for monitoring stations with span and precision requirements that are not otherwise achievable by the non-diluted EPA protocol test gas system, such as when a target concentration is lower than available test gas bottle concentrations. As with the non-diluted EPA protocol system, this system is enhanced by the use of the station data logger to control the span and precision process and data collection in the same manner if performed on site, remotely, or automatically. This standardizes the test process, while reducing process errors. Data logger control of tests and data averaging allows test results to be collected and reported by the central computer.

10.2 Equipment and Supplies

For a complete listing of supplies and equipment please see Section 8 of this standard operating procedure.

10.3 Logs and Forms

All actions at the site, scheduled and non-scheduled, are logged on forms. These forms are collected monthly, reviewed and filed together in monthly folders in the Maintenance files cabinet. Three complete calendar years of forms are readily available on site. The intent of these forms is to be able to recreate events and actions well after the fact. Examples of these forms can be found at the end of this subsection.

The forms in routine use are:

1. MONTHLY STATION/MET ACTIVITIES LOG (Figure 5)
2. MONTHLY SO₂ ACTIVITIES LOG (Figure 6)
3. MONTHLY MAINTENANCE REPORT FORM (Figure 7)

10.4 General Operations

This section provides an overview of scheduled inspection and preventive maintenance procedures. To minimize downtime and ensure data quality, preventive maintenance is to be performed on all gaseous monitors in the network according to a schedule established by the TSP, using the inspection criteria documented in this chapter. Below is a general summary of the types of maintenance checks performed.

Data from each site is evaluated daily. There is a daily morning review of overnight performance tests results, data validity flags, data completeness, data representativeness, logger messages, and shelter environmental status to determine if an immediate site visit is needed. Data loggers are contacted as needed to evaluate and configure instrument systems.

The Weekly inspection is performed once each calendar week and as needed.

Performance tests and QC precision tests are performed at prescribed intervals. Performance tests are automatically performed every night and QC precision tests are manually performed once every two weeks and are to be reported as the regulatory required bi-weekly QC precision test.

The Monthly inspection is performed on or near the beginning of each calendar month.

Upon completion of an inspection, log entries onto the STATION/MET log, SO₂ API 100 log, and into a “message to central” are required. Enter all tasks performed, and note any malfunctions or other actions needed or discovered during the inspection.

All scheduled checks are minimum requirements. Individual site circumstances may dictate a more frequent preventative maintenance schedule. Monthly, quarterly, and semi-annual inspections are always conducted by TSP-approved staff that has the training or experience to reliably perform the required checks or maintenance.

By contract agreement, it is the responsibility of all contracted site operators to notify TSP of any unusual instrument/equipment performance, possible malfunction, or outright malfunction, and action taken, if any. TSP in turn will take the appropriate action as soon as workload and priorities permit. TSP monitoring technician will summarize work performed in a “message to central” for all non-scheduled maintenance activities.

10.5 Routine Preventative Maintenance and Scheduled Activities

Preventive maintenance inspections and services should follow the recommended intervals by the EPA, the manufacturer, or as determined by actual experience. If preventive maintenance services are not being done according to the minimum guidelines of the manufacturer as set forth in this standard operating procedure, the TSP may jeopardize any claim to a manufacturer’s warranty and may jeopardize the validity of the data collected. The

preventive maintenance inspections are scheduled to provide an opportunity to detect and repair damage or wear conditions before major repairs are necessary and the loss of data occurs. The documentation of these activities is essential for QC tracking and for compliance with EPA’s Quality Systems methods. Site and analyzer log sheets along with “messages to central” are part of the official record and the documentation of maintenance or observations are to be written clearly and concisely and in accordance with good laboratory practices.

Table 3. Routine Preventative Maintenance and Schedule Activities

| Procedure or Resource | Description |
|--|---|
| Every Onsite Visit | |
| | Check station for general condition and proper operation of heating, air conditioning, lighting, and sample pumps. |
| 10.6.2 | Check all analyzers for faults and operability. Verify that the data logger is working correctly and reported values match the analyzer display. |
| Figure 2 | If equipped, observe the operating condition of zero air pack. Check for faults and short cycling. |
| | Remove trash when waste receptacles are full. Remove from shelter all odorous trash, such as leftover food and food packaging. |
| 10.6.8 Figure 5 | Leave a “message to central” and a site log entry summarizing purpose of visit and a summary of any significant findings or maintenance performed. |
| Weekly Inspection / Maintenance | |
| | Perform Every Onsite Visit inspection as defined above. |
| | Perform general housekeeping as necessary. Includes sweeping station as necessary. Dispose of trash as necessary. Clean up trash and remove weeds/vegetation from surrounding property. |
| Figure 5 Figure 6 | Note analyzer operational and diagnostic parameters on analyzer log sheets. <ul style="list-style-type: none"> • Check results from previous night’s Performance Test and record concentration levels on Analyzer Log Sheet • Using the log sheet as guidance, record the analyzer calibration factors and analyzer diagnostic test parameters on analyzer log sheet. |
| | Check SO ₂ analyzer display readout, data chart trace (if equipped) and data logger SO ₂ readout for agreement. Verify agreement between devices is within ±1 ppb |
| 10.6.6 | Inspect and empty water drop out system, (if equipped) – note on analyzer log sheet if water found. If flask is removed, perform a leak check after reassembling the system. |
| 10.6.3 | Inspect sample filter and replace once every 2 weeks at a minimum. If the sample filter is dirty, a change frequency of greater than once every 2 weeks is permissible. Leak check analyzer after filter change (10.6.6). |
| | Visually inspect the sample line inlet. Ensure the Teflon inlet shroud in place and free from insects and debris. Clean if necessary. |
| | Enter notes and initial analyzer log sheet |
| Figure 5 | Log all bottle gas supply pressures on station log sheet |
| Figure 5 | Log station maximum & minimum temperatures on station log sheet and reset thermometer if available. |
| Figure 5 | Enter notes and initial station log sheet |

| Procedure or Resource | Description |
|---|--|
| 10.6.8 | Leave a “message to central” and a site log entry summarizing purpose of visit and a summary of any significant findings or maintenance performed. |
| Every Two Week Period | |
| 10.6.10 | Perform Manual Quality Control Precision Test – Performed by APCD staff . |
| Monthly Inspection / Maintenance | |
| | Perform Weekly Inspection/Maintenance as defined above. |
| | Check associated power strips, wiring, power cables, and source and analyzer lines and fittings for wear, damage and proper installation. Ensure all power loads are evenly distributed across all building circuits. |
| | Inspect analyzer fan filters and clean as necessary (if equipped). |
| 6 | Check analyzer and Data Charts times against a National Institute of Standards and Technology traceable time piece (i.e. cell phone) and adjust if (>± 2 min) see analyzer manual or clock procedure. For changes to a data logger clock contact GMM supervisor or central PC staff first. |
| 10.6.4 | Check that the internal data acquisition program in the analyzer or the data chart is operational. |
| 10.6.3 | Replace sample filter. Leak check the analyzer. |
| 10.6.6 | Perform leak check of test gas manifold solenoid/s (if equipped) |
| Figure 5 Error! Reference source not found. | <p>Fill out new monthly station, analyzer, and calibrator (if equipped) log sheets for the upcoming month. The format of log sheets change over time. Follow the format of the current log sheet and be sure to include the following key elements:</p> <ul style="list-style-type: none"> • Analyzer log sheet – site name, month, year, analyzer range and analyzer firmware, analyzer SN and other appropriate info required by log sheet • Station log sheet - site name, month, year, bottle numbers, expiration date, concentration and pressure and other appropriate info required by log sheet • Calibrator log sheet - site name, month, year, model, firmware, SN and other appropriate info required by log sheet <p>Upon completion of the Monthly Maintenance site visit, all previous months log sheets are collected and placed in the monthly forms data collection box within 2 business days of being collected.</p> |
| Quarterly Inspections / Maintenance | |
| | None Required |
| Six Month Inspections / Maintenance | |
| | Inspect and clean the sample probe weather cap once every 6-months and when the sample line is replaced. Inspect the first 6” of sample line and calibration line for cleanliness. If dirty, trim 6” off the beginning of the line. |
| Annual Inspections / Maintenance | |
| | <p>Inspect and clean Heating, Ventilation and Air Conditioners (HVAC) units at site. Inspect for water access holes in the shelter, roof, and sides. Ensure AC unit is sealed against moisture on the shelter wall.</p> <ul style="list-style-type: none"> • Perform maintenance in June or July |

| Procedure or Resource | Description |
|--------------------------------------|--|
| | <ul style="list-style-type: none"> Replace or clean air conditioning and/or heater dust filters (if equipped) Clean air conditioner coils |
| 10.6.9 | In March or April, replace all sample lines annually. Inspect and clean the sample probe weather cap once every 6-months and when the sample line is replaced. Through the probe (TTP) calibration lines are to be replaced once every three years (2015, 2018, 2021, ect...). On years when the TTP calibration lines are not replaced, trim 6” off the inlet side of the calibration line. |
| 40 CFR Appendix B to part 136 | Perform Method Detection Limit (MDL) testing on NCore trace analyzers (reference CFR Method). These tests are only required at the NCore site and is the responsibility of the site operator to perform these tests. |

10.6 Maintenance Procedures

10.6.1 Disable/Enable Analyzer in Data Logger

ESC 8816/ 8832

Disable analyzer data channel:

From the top level menu, to disable a data channel from reporting to the data logger, the user must:

- Choose menu options **CDM (C Configuration Menu > D Configure (Data) Channels > M Disable/Mark Channel Offline)** to view the list of available channels.
- From the keyboard, using the down arrow button, scroll to the target channel name and hit the **Enter** or **Return** key. A limited list of channels that could be encountered includes:

| Channel Option | Instrument or Analyzer / Channel |
|-----------------------|---|
| O ₃ | Ozone Analyzer |
| O ₃ Cal | Ozone Calibrator |
| CO | Carbon Monoxide Analyzer/Calibrator |
| CO_Trace | Carbon Monoxide Trace Level Analyzer/Calibrator |
| NO | Nitrogen Oxide Analyzer |
| NO ₂ | Nitrogen Oxide Analyzer |
| NO _x | Nitrogen Oxide Analyzer |
| NO _y | NOY Analyzer |
| SO₂ | Sulfur Dioxide Analyzer |

- Next, hit the **Esc** (Escape) key twice to get back to top level menu.
- Select menu option **DF (D Real-Time Display Menu > F Display Readings w/flags)** to ensure the proper machine was disabled. You should see the letter “D” within parenthesis and adjacent to the targeted channel indicating it has been disabled.

Enable analyzer data channel:

From the top level menu to enable the data channel to resume reporting to the data logger, the user must:

1. Choose menu options **CDE (C Configuration Menu > D Configure (Data) Channels > E Enable /Mark Channel Online)** to view the list of available channels.
2. From the keyboard, using the down arrow button, scroll to the target channel name, and hit the **Enter** or **Return** key.
3. If all machines/instruments and/or channels are already on line, the user will receive a message stating “No channels are offline” at the bottom left screen. Otherwise a list of channel names will appear.
4. Next, hit the **Esc** key twice to get back to the top level menu.
5. Select menu option **DF (D Real-Time Display Menu > F Display Readings w/flags)** to ensure the proper channel was enabled. You should see parenthesis adjacent to the targeted channel without the letter “D” inside indicating the machine/instrument channel is enabled and reporting to the data logger.

Agilaire 8872

Disable analyzer data channel:

1. After logging in to AirVision , if the Site Node Logger Toolbox is not open, from the top level menu select the **Home** tab > **Utilities** > **Site Node Logger Toolbox** > then select the **Channels** tab.
2. Identify the channel to be disabled. At the right side of the form, under the “Disabled” heading, click on the row with the target channel name. This action will change the channel state from “False” to “True” indicating that it is now disabled and not reporting to the data logger.

Enable analyzer data channel:

1. After logging in to AirVision , if the Site Node Logger Toolbox is not open, from the top level menu select the **Home** tab > **Utilities** > **Site Node Logger Toolbox** > then select the **Channels** tab.
2. Identify the channel name to be enabled. At the right side of the form, under the “Disabled” heading, click on the row with the target channel name. This action will change the channel state from “True” to “False” indicating that it is now enabled and will now report to the data logger.

10.6.2 Check Analyzer Calibrations Factors and Diagnostic Test Parameters Procedure

The SO₂ analyzer contains a list of test parameters which provide health status and active measurements. Test parameters have an allowable operating range specified on the log form. Monthly and weekly logging activities require verification and recording of these parameters.

On SO₂ analyzer front panel are two function buttons, < **TST** and **TST** >, as shown in below figure. The **TST** > button allows the operator to step down through the parametric value list, while the < **TST** button allows transition up through the list. Both buttons cycle back to their start point.

Not all analyzer parameters are required on the log form. Changes occur to the form when a parameter is added or removed. Newer analyzers also have slightly different parameters, or different orders. A matrix of SO₂ analyzer parameters and respective log entries follow:

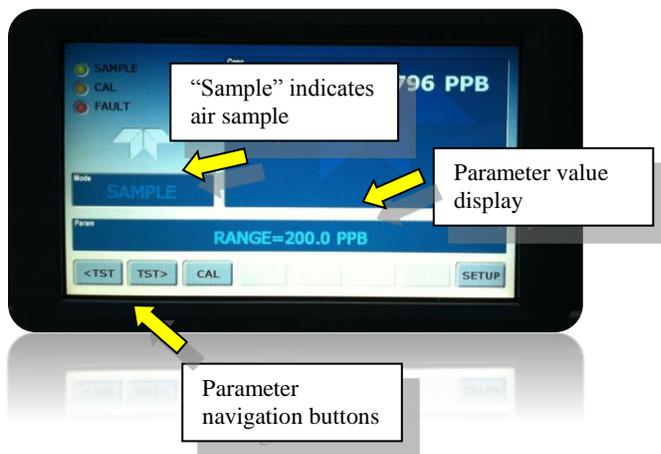
| Analyzer Parameter | Log Form Parameter |
|---------------------------|---------------------------|
| PRES | Sample Pressure |
| SAMP FL | Sample Flow |
| NORM PMT | Normal PMT |

| | |
|------------|----------------------------|
| UV LAMP | UV Lamp |
| LAMP RATIO | Lamp Ratio |
| SLOPE | Slope |
| OFFSET | Offset |
| HVPS | HVPS |
| RCELL TEMP | R Cell Temp |
| BOX TEMP | Box Temp |
| PMT TEMP | PMT Temp (check stability) |
| TIME | Clock |
| (NA) | Filter |
| (NA) | Leak Check |

During monthly or weekly inspections complete the log form as outlined below:

1. Hit the, **TST >** button to find the first value on the log form.
2. Sequentially record each value requested by the log form.
3. At “Clock” field, verify analyzer time is within 2 minutes of data logger time. If not, correct the time (10.6.7).
4. Change the filter per according to schedule (10.6.3).
5. Perform a leak check on the analyzer according to schedule (10.6.6).

Once finished logging, ensure analyzer is in “Sample” mode (see below figure). “Sample” indicates analyzer is in the normal ambient air sampling mode.



10.6.3 Filter Change Procedure

1. Disable SO₂ channel from data logger (10.6.1)
2. Remove filter glass casing (analyzer front panel door). Place it upside down on flat surface, still containing the glass.
3. With tweezers, remove old filter and security ring from housing. Place ring on glass to keep clean.

4. Position a new 1um filter in filter housing using tweezers for filter, and also to place security ring over filter.
5. Gently hand-tighten filter holder being careful to keep glass centered. If not centered, lens will chip or break when casing is tightened!
6. Inspect lines and fittings for seal.
7. Perform leak check from back of analyzer (10.6.6.1).
8. Enable SO₂ channel on data logger (10.6.1).

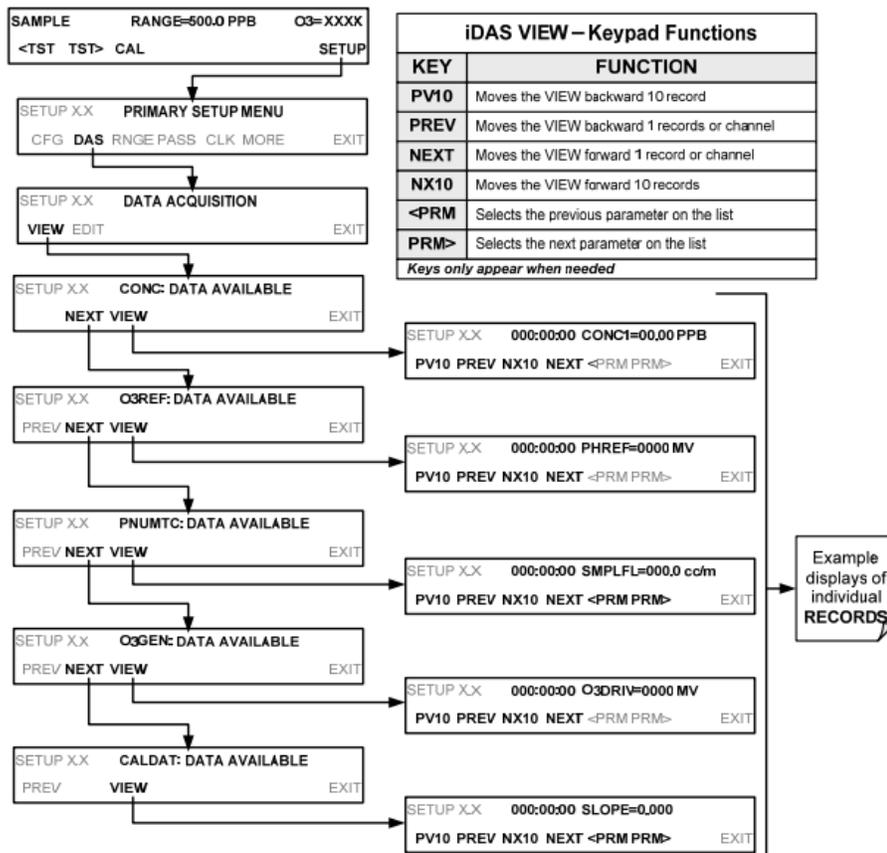
10.6.4 Internal Data Acquisition System Verification

The purpose of this procedure is to ensure that the internal data logging capabilities of the analyzers are functioning properly. The procedure was taken from the TAPI SO₂ analyzer manuals.

TAPI Analyzers

To verify internal data logging:

1. Access the internal data stored on the analyzer through the front panel: **SETUP > DAS > VIEW**, refer to Figure 1 below for menu structure
2. Verify data is stored by selecting the first data channel and pressing **VIEW**, then press **PV10** several times to view whether data was stored since the last data acquisition verification was performed
3. Press **EXIT > NEXT > VIEW > PV10** to verify data in the other data channels
4. At a minimum, verify one parameter for each data channel
5. Continue to press **EXIT** until the analyzer returns to the sample mode



TAPI iDAS menu structure

6. If data is not being stored, notify appropriate personnel
7. Fill out the required data acquisition verification entry on the Monthly log sheet

10.6.5 Bottle Change Procedure

1. Make note of the pressure left in the old bottle (psi).
2. Close the old gas bottle valve (clockwise turn).
3. Remove the gas line from the back of the dilution calibrator for NO, SO₂ and some CO; most CO cylinders are connected directly to the analyzer.
4. Inspect the line and fittings and replace as necessary.
5. Remove the two-stage regulator from the gas bottle.
6. For 660 CGA stainless regulators install a new Teflon washer onto the stem connection.

7. Connect the regulator to the new gas bottle.
8. If replacing the regulator, move the calibration gas line from the old to the new regulator.
9. Purge the regulator and line:
 - a. Using a quick connect with a push stop or your thumb over the end of the gas line, cap the gas line closed.
 - b. Back off the regulator pressure knob, and close the regulator valve.
 - c. Open the gas bottle valve until the bottle-side pressure gauge reads the bottle psi.
 - d. Close the gas bottle valve.
 - e. Open the regulator valve and the gas line until the regulator gauges go to zero psi.
 - f. Close the regulator valve and the gas line.
 - g. Repeat for a total of three times
10. Connect the gas line back to the appropriate gas port on the back of the dilution calibrator or SO₂ analyzer (if applicable), vent gas out of the line before tightening the fitting to ensure that gas is flowing through the line.
11. Set the regulator pressure to 30psi and ensure that the gas bottle valve and regulator valve are open, if connected to a calibrator verify that the gas pressure is within the required range.
12. Make note of the bottle change on the station log and record the new bottle number, gas type, concentration, expiration date and pressure.
13. Send two messages to central through the data logger (see 10.6.8)
 - a. The first message will consist of the designation of “old”, old bottle number, concentration(s), expiration date, and current bottle pressure.
 - b. Use the following format.
 - i. **Bottle Change Old FF40348 NOx 9.89 NO 9.74 07/29/16 600**
 - c. The second message will consist of the designation of “new”, **new** bottle number, concentration(s), expiration date, and current bottle pressure.
 - d. Use the following format.
 - i. **Bottle Change New FF55716 NOx 9.81 NO 9.9 07/29/16 1000**
 - e. Substitute the labels “SO₂”, “CO” for “NO, NOX” as needed in the messages.
14. Enter the new bottle concentration into the 700 calibrator if different than old bottle
 - a. On the 700 calibrator, press Setup > Gas > Cyl > Port(n) where n is the appropriate port number 1-4 connected to the gas bottle

- b. On the 700 calibrator, make sure the displayed analyte is the correct bottle. Press Edit and use the keys to enter the new concentration. The units can be changed if necessary but under normal circumstances it should stay the same.
- c. When finished, press Enter (or Exit to cancel) and press exit enough times to return to the main screen.

10.6.6 Leak Check Procedures

The purpose of this procedure is to provide guidance on determining the presence of a leak in the sample stream. The sample stream can consist of the analyzer, a water drop-out, and a sample line. This procedure also outlines how to determine if the sample manifold on a dynamic dilution calibration check system is leaking.

10.6.6.1 Determination of Sample Stream Leak

1. Disable analyzer channel on data logger (10.6.1).
2. On the front panel of the SO₂ analyzer view the sample pressure parameter using the TST > key
3. Cap the sample stream. Either:
 - a. Disconnect the sample line and cap the sample inlet on the back of the analyzer (analyzer leak check).
 - b. Or cap the end of the water drop-out furthest from the analyzer (water drop-out leak check).
 - c. Or cap the end of the sample line (sample stream leak check).
4. Monitor the sample pressure until a reading of less than 10" (255 mm) of mercury is reached.
 - a. If pressure is reached within 2 minutes, the leak check has passed.
 - b. If pressure is not reached within 5 minutes, leak check has failed, troubleshoot or seek assistance from a monitoring technician.
5. Uncap the sample stream by reverting steps taken in step 3.
6. Enable analyzer channel on data logger (10.6.1).
7. If the leak check fails, leave a message for central detailing findings, actions taken, and initials (10.6.8). Note: a high sample pressure may also indicate a weak sample pump.

10.6.6.2 Determination of Calibration Solenoid Manifold Bank Leak

1. Using the data logger, energize the solenoid that allows gas to escape to the room (usually labeled as the dump solenoid).
 - a. On an 8832, from the main screen select D > O (Display > Outputs) and scroll to the appropriate digital output. Press C for closed (O will open) – in this case the C and O refer to the circuit and C means “energize” while O means “de-energize”.
 - b. On an 8872, in the Site Node Logger Toolbox, switch to the Digital Outputs tab and click the State button in the row with the Dump Solenoid. The State button will change from OPEN to CLOSED indicating the circuit is energized.

2. On the 700, generate zero air at 2-3 Lpm while watching the pressure needle on the solenoid manifold.
 - a. Press the “Gen” button
 - b. Press the “Auto” button
 - c. Press the “Species” button until “zero” appears (it may read CO/SO₂/NO, etc). The “Species” button selects the type of gas the dilution calibrator will generate. The factory default selection when entering into this menu is typically “zero”.
 - d. Press Enter
 - e. Adjust the total flow to between 2 and 3 Lpm and press enter
3. When the pressure needle reaches > 20 (but preferably less than 30) psi, put the 700 into Standby mode.
 - a. It is normal for the pressure needle on the manifold to drop when putting the 700 into Standby. Use the post-drop number for this test.
4. Watch the pressure needle for 2 minutes. A drop of less than 5 psi over 2 minutes indicates there is no sufficient leak.
 - a. If a drop of < 5 psi occurs in 2 minutes, the leak check has passed.
 - b. If a drop of > 5 psi occurs in 2 minutes, troubleshoot the manifold or the 700 (the leak could be in either in this test) or contact the site operator.
5. Revert steps taken in step 1 to de-energize the dump solenoid.
6. If leak check fails, leave a message for central detailing findings, actions taken, and initials (10.6.8).

10.6.7 Time Change Procedure

The following describes the standard procedure to change the time on the TAPI SO₂ Analyzer and the Data Chart. First compare the Analyzer/Data Chart’s time with the Data logger, if it is out of the +/- 2 minute specification, then adjust the Analyzer/Data Chart’s time. Check the Data logger’s time with cell phone time, if it is significantly off, contact the Data Manager.

Important Note! – All times on data loggers and analyzers are to be set to Mountain Standard Time and do not adjust for daylight savings. Data logger and analyzers clocks should appear to be running 1 hour late from March to November (daylight savings time period, clocks move one hour forward). Reference a calendar or other source to determine the exact and end dates of daylight savings.

TAPI SO₂ Analyzer

This procedure was taken from the TAPI SO₂ analyzer manual. For any time changes done to the analyzer make a note on the analyzer log sheet.

1. Using the **TST >** keys toggle to the TIME Display and determine whether a time change is necessary.
2. If the time needs to be adjusted, from the home menu press: **SETUP > CLK > TIME**
3. Toggle the numbers up or down to get the correct time

4. Press ENTER
5. EXIT to the home menu
6. Make a note on the SO₂ log sheet of the time change

Data logger

If the clock on a data logger is incorrect, there may be more serious issues to consider including data validity and proper operation of the data logger. If the clock is incorrect contact the Data Manager.

10.6.8 Message to Central Procedure

ESC 8816 or 8832

1. Log in to the data logger.
2. From the top level menu Type **SMC (S Status Menu > M Message Menu > C Leave a Message for Central)** followed by hitting the **Enter** or **Return** key.
3. When the text entry display appears, type in up to 80 characters of text explaining the site visit, followed by your initials, example, “Weekly completed. No problems noted. – JJ” then hit the **Enter** or **Return** key on the keyboard to accept the log entry.

Agilaire 8872

1. Log in to the data logger using the AirVision application.
2. Select the **Home** tab > then **Data Editors** drop down menu.
3. From the drop-down menu select, **Log Book Entry Editor**, and click the round green icon with white “plus” symbol, entitled, **New Log Entry**.
4. Next, click on the **Category:** drop-drop down menu and choose **Logger Message**.
5. Select the drop-down menu item, **Site** and choose the appropriate site, for example, **Welby**.
6. Enter text explaining the purpose of the site visit, followed by your initials. Example, “Weekly completed. No problems noted. – JJ” hit the **Save** button at the top left to save your comments. The application will allow more characters than 80, but they are truncated for the Central computer.

10.6.9 Line change Procedure

1. All sample lines are to be changed annually or as needed if defects are suspected. Sample lines should be trimmed (at the probe end) by approximately 1 ft. six months after installation. Through the probe calibration lines are to be changed once every three years or when defects or degradation are suspected.
2. Disable analyzer channel on data logger (10.6.1).
3. Perform a leak check on the existing sample line to confirm data validity prior to changing the line (10.6.6).
4. Remove the existing line and measure out and cut a length of new sample line of approximately the same length as the old line plus at least an additional foot. Be sure to have enough excess inside the

shelter to allow for effective analyzer calibrations. Use a designated tubing cutter to cut the Teflon tubing to ensure the cut is straight, at a 90 degree angle to the tubing's outer wall, and not beveled.

5. Cover or cap the end of the new line prior to installation. This ensures dirt does not enter the line during the installation process. Remove the line cover or cap once the line is installed.
6. Record the final length of the sample line.
7. Ensure fittings used in the sample train are made of Teflon.
8. Clean water dropout manifold (if equipped).
9. Perform a leak check on the new sample line (10.6.6).
10. If the line replaced is a sample line, note sample line length and determine residence time. All Residence times must be < 20 sec. The calculation of residence time requires knowledge of the sample flow rate, length of sample line, additional static volumes such as water dropouts, and the internal cross-sectional area of the tubing. When determining an additional static volume, as with a water dropout, use only the volume that sees active gas flow. For example, the water catch flask on the bottom of the water dropout should not be included in volume calculations, only the upper portion of the manifold. Below is a table of internal cross-sectional areas for common types ¼ Teflon tubes that can be use in residence time calculations.

Table 4. Internal Cross-Sectional Area for Teflon Tubing

| Tubing Diameter | ID | OD | ID Area |
|--------------------------|--------|---------|-----------------------|
| Thin Wall (3/16 x 1/4) | 4.8 mm | 6.35 mm | 18.10 mm ² |
| Medium Wall (5/32 x 1/4) | 4.0 mm | 6.35 mm | 12.57 mm ² |
| Thick Wall (1/8 x 1/4) | 3.2 mm | 6.35 mm | 8.04 mm ² |

(Note* 1 cm³ = 1 ml)

Equation 7. Residence Time

$$Residence\ Time\ (sec) = \left(\frac{\left(\frac{(ID\ area\ of\ tube\ (mm^2) \times Tube\ Length\ (in) \times 2.54 \left(\frac{cm}{in}\right))}{100 \left(\frac{mm^2}{cm^2}\right)} + Static\ Vol.\ (cm^3) \right)}{Sample\ Flow\ \left(\frac{cm^3}{min}\right)} \right) \times 60 \left(\frac{sec}{min}\right)$$

11. Enable analyzer channel on data logger (10.6.1).
12. Note line change activities on log sheet.
13. Enter message to central, including the new residence times and/or sufficient information to determine residence time based upon the analyzers flow rate (10.6.8).

10.6.10 Perform Manual Precisions

ESC 8816 or 8832

1. Login to the data logger.

- From the top level menu type **CCS (C Configuration Menu > C Configure Calibrations > S Start a Calibration Program.)**
- A list of calibration options appears (see figures below.) To run a manual SO₂ QC Precision test select, **QC-SO₂** by scrolling to that option and hitting the **Enter** or **Return** key.

```
ESC 8832 v2.14 ID:63    Choose List (Enter to Select)    08/28/13 15:39:31
CO-SP-Z
CO-Z-PRE
QC-CO
QC-SO2
SO2-SP-Z
SO2-Z-PR
```

CCS Menu Option Results

- Hit **Esc** (escape) key twice for the top level menu. Type, **DF** to verify the QC Precision test was initiated. You should see the letter, “C” next to the SO₂ line indicating it is now calibrating. For SO₂ it may run 20 minutes or longer. After completion, allow time for the data logger to update. Once updated the new precision value will appear in the **RL** list.

```
ESC 8832 v2.14 ID:63    Real-Time Engineering Flags    08/28/13 16:03:21
CO= 0.4608    ( )
CO_PPB= 460.8    ( )
SO2= 20.555    ( C )
SO2MAX= -1.798E+30    ( )
ACTCONC= 20    ( )
ITEMP= 79.05    ( )    COINTTMP= 40.9    ( )
COCHMTMP= 48.19    ( )
```

“C” indicates a Calibration is currently running.

- Hit the **Esc** key twice to get to the top level menu then type **RL** to view results as shown below.

```
QC-SO2 08/19 08:12 -EXPECTED- --ACTUAL-- --ERROR--- -UNITS-- -----
FLAGS-----
SO2
SO2-PREC 20.00 ↔ 20.05 0.04608 PPM
SO2-ZERO 0 ↔ 0.00469 0.00469 PPM
```

A manual QC Precision was run Aug 19 at 08:12

Agilaire 8872

- Login to the 8872 data logger.

2. From the **Home** tab select **Utilities > Site Node Logger Toolbox**.
3. When the **Site Node Logger Toolbox** tab appears, select the **Calibration** tab and click on the proper calibration sequence. Each QC manual Precision choice will have QC” in the Sequence Name. If a sequence has “PRE” or “PR” in the name, it is primarily for nightly Performance tests.
4. Select **Start** at the right side of the window, in the “QC-SO₂” row to run the QC-SO₂ manual Precision. Next, look in the “Phase Name” column to see the current phase (progress) of the calibration. For SO₂ and NO₂ it can take up to an hour or longer to get results. For CO and O₃ it takes approximately 25 minutes.
5. Once the Precision has completed, on the **Home** tab click **Reports**. From the drop-down menu, select **Calibration Results**.
6. When the “Report Criteria” window appears, notice the “Parameter Selection” section. On the keyboard, hold the **Ctrl** button down and click on each parameter for which you wish to see calibration results. Options are, **ACTCONC**, **CO**, **NO**, **NO₂**, **NOX**, and **O₃CAL**, and **SO₂**. Select all or a subset depending on the site, available equipment, and result needed.
7. Now look at the “Date Range” section of the window. Modify the “Start Date” and time and “End Date” and time to coincide with the Precisions just run.
8. Finally in the “Calibrations Results” section click on **Generate Report** to see the Precision results, presented in a report format.
 - a. The “Value” column will show the average value collected by the analyzer. The “Expected Value” column contains the value that should have been generated by the calibration equipment. With O₃, the O₃ Cal “Expected Value” column shows the value the O₃ calibration equipment was attempting to generate and the “Value” column shows what it actually did generate. With NO₂, the ACTCONC section “Expected Value” column shows the value the NO₂ calibration equipment was attempting to generate and the “Value” column shows what it actually did generate.
9. Import the Manual QC Precision results into the ZSP Tracking Database. This procedure can be found in the Gaseous and Meteorological Data Validation SOP, Appendix D3.

10.7 Calibration Standards

Refer to the Standards Verification/Calibration SOP (Appendix QA3) in the CDPHE/APCD/TSP QAPP for more detailed information on standards and traceability of gas standards.

11 HANDLING AND PRESERVATION

Atmospheric sulfur dioxide concentrations are monitored continuously; no discrete samples are collected, handled, or preserved. Therefore a section for sample handling and preservation in this SOP is not required.

12 SAMPLE PRESERVATION AND ANALYSIS

Sulfur dioxide samples receive no special preparation prior to analysis. Therefore a section for sample preservation and analysis in this SOP is not required.

13 TROUBLESHOOTING

13.1 Environmental Factors

Environmental conditions can play a role in the operational characteristics of analyzers. Some external factors may be constant while others are sporadic in nature. External factors to check include:

1. Is the shelter temperature stable throughout the day?
2. Is vibration from other equipment causing an affect?
3. Is the air conditioner or heater blowing directly on the instrument?

13.2 General Factors

Other factors linked to the shelter and manifold design can contribute to data loss. The sample probe, water dropouts, sample lines and external pump lines should be checked on a regular basis to ensure integrity. Dirty sample lines can artificially suppress readings of reactive analytes. Low sample flow rates causes increased residence times within the sample train and may lead to the premature degradation of reactive species. Sample pumps should be maintained to ensure proper flow rates. Sample line bulkhead fittings to the exterior of the shelter are to be sealed to prevent inside air from exiting the shelter near the sample inlet resulting in a biased measurement. Power to the site is another factor that can contribute to data loss. Incoming power needs to be stable and have a good waveform. All power strips are to be in good working order and power loads are to be balanced across all station outlets.

13.3 Instrument Troubleshooting

Troubleshooting of problems with analyzers is specific to each analyzer and its design. Common problems with instruments include:

1. Low or erratic flow
2. Erratic or noisy readings
3. No readings or off-scale readings
4. No display
5. No output
6. Analyzer completely inoperative

Troubleshooting sections in specific analyzer operation and service manuals, located at each site or in the APCD office, should be consulted to assist in resolving instrument problems.

Chapter 12 outlines troubleshooting techniques in both the 100E and T100 manuals, and Chapter 8 in the T100U manual. Troubleshooting techniques for the data logger and supporting sample system parts or components, including external solenoid manifolds and calibration systems, are the purview of their respective manuals and the experience of qualified operators.

14 DATA ACQUISITION, CALCULATIONS, AND DATA REDUCTION

All data is collected, stored, and retrieved digitally from data loggers. The terms data logger and onsite data acquisition system (DAS) are used interchangeably throughout this SOP.

14.1 Data Acquisition

The APCD/TSP data acquisition system is comprised of three components: an onsite primary data acquisition system that collects data from all continuous monitoring equipment, an onsite secondary data acquisition system, or back-up system that collects data from the continuous monitoring equipment, and a centralized polling system that routinely collects data from the primary data acquisition system and stores it in a SQL database for processing and validation.

14.1.1 Primary Onsite Data Acquisition Systems

The APCD employs three different models of onsite DAS in the operations of its air monitoring network. These are the ESC 8816 data logger, the ESC 8832 data logger, and the Agilaire 8872 data logger. The 8816 data logger is the oldest type of data logger in the network and is a predecessor to the 8832 and 8872 data loggers. See Section 8.1.4 for a more detailed description of these data loggers.

14.1.2 Secondary Onsite Data Acquisition Systems

The APCD uses a backup data acquisition system to provide backup data in case of failure of the primary systems. The backup data acquisition system is the analyzer based on-board data acquisition systems that are unique to each manufacturer. In the event an on-board data acquisition system is not available, a digital strip chart recorder can be used. Internal data logging is available on the newer Thermo and TAPI analyzers. A description of these secondary data acquisition system is as follows.

Teledyne iDAS System

The TAPI internal data acquisition system (iDAS) is available on all analyzers. The non-volatile memory retains the data even when the instrument is powered off or the firmware is updated (back up before update advised). Access to the iDAS is available either through the front panel or the APICOM remote interface. The remote interface allows for data to be automatically downloaded to a remote PC. The iDAS is flexible in the parameters stored and triggering events to initiate data storage. The maximum iDAS data storage is limited to the analyzers available memory and the number of data parameters and channels.(Teledyne-Monitor Labs, 2009)

14.1.3 Central Polling System

The APCD uses the AirVision software package for its central data management system. AirVision is a centralized data management and polling software system that is used to acquire, edit, validate, analyze, and report air quality data. AirVision supports open data acquisition and data imports thru modular drivers that can be added to provide connectivity to a data source. The system has combined data editing and quality control tools that can be utilized in evaluating and validating data in the post-processing environment. The post-processing environment allows user control of the data from the management of raw data within the server environment through the exporting of validated data through built in reports or for external statistical evaluations and reporting. A more detailed description of this application can be found in APCD's Data Logger and Central Polling Standard Operating Procedure.(Agilaire, 2009)

Central Polling Daily Tasks

1. Task managers within Air Vision polls data from remote air quality monitoring sites at the top of each hour, at a minimum. Some sites may be polled at a greater frequency depending upon data needs. Data from each site is stored in a SQL database and made available for review and analysis after polling has been completed.
2. Ambient data on the AirVision Central polling computer is reviewed every business day in the morning, the previous 24 hours (or 3 days on Mondays) worth of data is reviewed for completeness and accuracy. This data review is used to determine if a physical site visit is required.

3. Low level (precision) and high level (span) test gas sequences are run on alternate days. The precision and span level tests are followed by a zero test and a two-minute recovery period. The results are reviewed each morning and plotted on control charts. It is the responsibility of one individual within TSP to review the daily Zero/Span results, plot them on the control charts, and notify the technician responsible of any out of control condition. "Out of control" is defined as:
 - a. trending toward warning limit as defined on the control chart
 - b. points plotted exceeding the warning limit
 - c. points plotted exceeding the action limit as defined on the control chart

14.2 Calculations and Data Reduction

As mentioned above, data collected on a DAS are available as soon as the averaging period is complete. Data are polled automatically via modems (analog phone, wireless cellular, or DSL) by the Central polling computer hourly. If needed, sub-hourly polls or remote checks can also be performed.

Data from the continuous air monitoring equipment are generally stored at hourly and minute resolution averages. The software on the Central polling computer stores the downloaded minute and hourly averages and is capable of aggregating these averaging intervals into larger averaging intervals such as 8-hour or 24-hour averages.

A more detailed description of the DAS is given in the CDPHE/APCD/TSP QAPP Appendix D1 and in the manufacturers' manual.

14.2.1 Zero Adjustment Methods

SO₂ analyzers base line response, as measured by the nightly performance checks, can change over time at a significant magnitude relative to the analytical system's method detection limit. Base line shifts can occur for numerous reasons, these reasons can include changes in lamp intensity due to normal aging, accumulation of dirt and contaminants in the sampling systems, and detector drift. A drifting baseline does not necessarily necessitate the invalidation of data. If the drift is small and reproducible over the course of several days, then post processing of data to remove the baseline bias can be performed. A more detailed description of APCD's zero adjust methods can be attained in APCD's Gaseous and Meteorological Data Validation SOP, Appendix D3.

15 COMPUTER HARDWARE AND SOFTWARE

The data acquisition system (DAS) used by the APCD/TSP for collecting data from continuous air monitors is generally described in Section 14 and in the CDPHE/APCD/TSP QAPP.

The primary DAS Central polling computer is a Windows based server. The AirVision data system on this server provides for the polling of sites using dial-up modems and broadband access for data. A printer is attached to the system for printing out reports. The primary repository for data, and the engine for information assembly, is a Microsoft SQL Server operated and maintained by the Governor's Office of Information Technology. The CDPHE/APCD/TSP maintains a database owner position responsible for logical maintenance of the data system.

The 8872 is a Windows based PC with attached monitor, keyboard, and mouse. The 8832 and 8816 are proprietary hard-circuit systems that may or may not have attached screens and keyboards. Sites usually include other computer hardware and software such as switches, RS232 cables, Ethernet cables, and analog cables.

16 DATA MANAGEMENT AND RECORDS MANAGEMENT

16.1 Data Management

Data are generated from the analyzer at intervals internally set, ranging from an averaging time of 20 seconds to 5 minutes. The data is collected by the on-site data logger as near-real-time data (often every 3 to 10 seconds) and is aggregated into 1-minute averages, which are in turn aggregated into 1-hour averages. Some data streams may be stored at a third averaging interval, meteorological data can be stored as a 15-minute average and SO₂ data can be stored in a 5-minute average. Note the capacity of the on-site data logger is limited to three time-base averaging intervals and that the 5-minute SO₂ average supersedes the 15-minute meteorological average. The Central polling computer collects these averages routinely.

For reporting purposes, other averaging intervals are derived, such as an 8-hour moving average for ozone. In these cases, the data is aggregated by the Central polling computer for the purpose of the report and are often not stored independently. The Central polling computer connects to a SQL server, which is maintained, and backed up, by the Office of Information Technology.

Data are sent to the EPA centralized Air Quality System (AQS) database for long-term storage. The APCD submits both hourly average and hourly 5 minute max data to AQS. Additionally, the data are stored and archived by the APCD/TSP in both electronic and hard copy formats. Monthly electronic data files and related printed material packets (maintenance forms, etc.) are produced.

A more detailed description of the data management is given in the Gaseous and Meteorological Data Verification SOP, Appendix D3 in the CDPHE/APCD/TSP QAPP.

16.2 Records Management

Continuous ambient air monitoring data are archived both in electronic and hard-copy formats. Electronic data and calibration files from the primary data acquisition system are archived. Data from the backup electronic strip chart recorders, where used, are downloaded annually and archived on a computer hard drive. Hard copy printouts of the data are kept at the APCD office for a minimum of three calendar years before being sent to an off-site archive/storage facility.

17 QUALITY ASSURANCE AND QUALITY CONTROL

The APCD has in place robust Quality assurance (QA) and quality control (QC) programs to ensure all methods and procedures are done accurately and systematically to ensure data quality. QA and QC are two terms commonly discussed, but often confused. Quality assurance refers to the overall process of ensuring that the data collected meet previously stated Data Quality Indicators (DQI) and associated measurement quality objectives (MQOs). The principal DQIs are precision, bias, representativeness, completeness, comparability, and sensitivity. The principal MQO's are parameter specific and are listed in CDPHE's QAPP. Quality control covers specific procedures established for obtaining and maintaining data collection within those limits. Field staff are predominantly responsible for the implementation of QC procedures, however, data attained from these procedures is utilized in QA evaluations.

17.1 Quality Assurance

The goal of the quality assurance program is to control measurement uncertainty to an acceptable level through the use of various QC and evaluation techniques. The entire Quality Assurance effort put forward by the APCD is too large to include here. The scope of this SOP will describe efforts taken by site operators and data validation personnel to ensure the quality of the data collected meets standards set forth in various sections of the *Code of Federal Regulations*. For a complete description of the QA and QC process undertaken by the APCD, see the appropriate quality assurance appendices in the QAPP. Two of the most significant Quality Assurance procedures are described below.

17.1.1 Audits

Audits are evaluation processes used to measure the performance of effectiveness of a system and its elements. APCD quality assurance staff performs two types of audits. These audits are performed at a frequency as described in APCD QAPP.

Systems Audits - A systems audit is an on-site review and inspection of an ambient air monitoring program or air monitoring site to assess its compliance with established regulations governing the collection, analysis, validation, and reporting of ambient air quality data.

Performance Audits - A performance audit is a type of audit in which the quantitative data generated in a measurement system are obtained independently and compared with routinely obtained data to evaluate the proficiency of an analyst, laboratory, or measurement system. Two types of performance audits are discussed below.

- Monitoring Organization Performance Audits - These performance audits are used to provide an independent assessment of the measurement operations of each instrument being audited. This is accomplished by comparing performance samples or devices of “known” concentrations or values to the values measured by the instruments being audited.
- National Performance Evaluation Program (NPEP) – These performance audits are implemented at the federal level although some programs may be implemented by the monitoring organizations if certain requirements are met.

17.1.2 Data Quality Assessment

Data Quality Assessment is used to assess the type, quantity, and quality of data in order to verify that the planning objectives, Quality Assurance Project Plan components, and sample collection procedures were satisfied and that the data are suitable for its intended purpose. Data Quality Assessment is a five-step procedure for determining statistically whether or not a data set is suitable for its intended purpose. This assessment is a scientific and statistical evaluation of data to determine if it is of the type, quantity, and quality needed and is performed annually by quality assurance staff to check if objectives were met.

17.2 Quality Control

Quality Control is the overall system of technical activities that measures the attributes and performance of a process, item, or service against defined standards to verify that they meet the stated requirements established by the EPA. Quality control includes establishing specifications or acceptance criteria for each quality characteristic of the monitoring/analytical process, assessing procedures used in the monitoring/analytical process to determine conformance to these specifications, and taking any necessary corrective actions to bring them into conformance.

Quality control refers to procedures established for collecting data within pre-specified tolerance limits. These pre-specified tolerances are defined in the Measurement Quality Objectives as defined in APCD’s QAPP. While all QC procedures are important, the most significant procedure employed by the APCD is the routine measurement of a known test gas by gaseous analyzers. All procedure documented in this SOP are QC procedures because they allow the analytical systems to continue running in exceptional condition and serves to minimize out-of-control conditions as defined by APCD MQO’s. By definition, the creation and use of this SOP is a QC function. All QC procedures are described in Sections 9 and 10 of this SOP. Three of the most significant QC procedures are described below.

17.2.1 Performance and Precision Tests

A primary quality assurance task carried out by site operators is the performance of routine QC checks. The APCD performs two types of QC checks at designate precision level test gas concentrations. These two tests are called Performance checks and QC Precision checks. The Performance check is an automated performance test that is performed nightly and is used to evaluate the health of the sample system. The QC Precision check is a manual evaluation performed by qualified personnel who can attest to their validity and are reported to the EPA. The

former are not reported to the EPA to prevent an artificial bias introduced by sample pools of different size. Sites operated by subcontractors are not required to manually perform QC Precision checks. Instead, one performance check is selected at random from each two-week period to satisfy the QC Precision check requirement. The performance check is selected by APCD personnel and is included with the APCD-operated QC Precision check submission to the EPA's AQS.

For instructions on performing a manual QC precision test, see Section 10.6.10.

17.2.2 Calibrations

Calibration of an analyzer or instrument establishes the quantitative relationship between the actual value of a standard, be it a pollutant concentration, a temperature, or a mass value, and the analyzer's response (chart recorder reading, output volts, digital output, etc.). This relationship is used to convert subsequent analyzer response values to corresponding concentrations. Once an instrument's calibration relationship is established, it is checked at reasonable frequencies to verify that it remains in calibration. It is the goal of APCD to perform calibrations on all analyzers quarterly, however, circumstances may require calibrations be performed at the longer frequency of every 6-months. A 6-month calibration frequency still meets EPA recommended calibration frequency criteria.

For instructions on performing a calibration, see Section 9.

17.2.3 Documentation

Documentation is an important component of the QC system. Extensive certification paperwork and log sheet must be rigorously maintained for procedures, standards and analyzers. APCD takes special care to prepare and preserve electronic and paper backup copies of all site log sheets, ambient sample data, QC data, and calibration data. All data and supporting documentation should be held on-site for a minimum of three calendar years then sent for offsite archive. See Section 16 for additional information.

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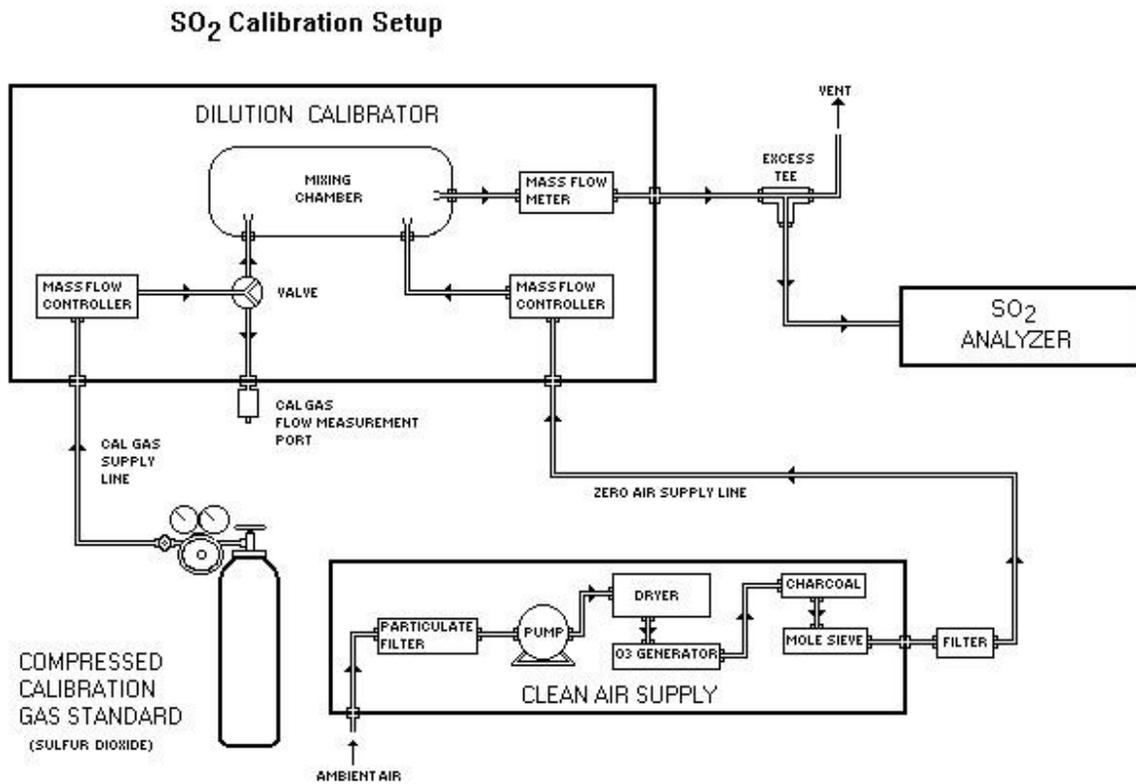


Figure 1. SO₂ Calibration Setup

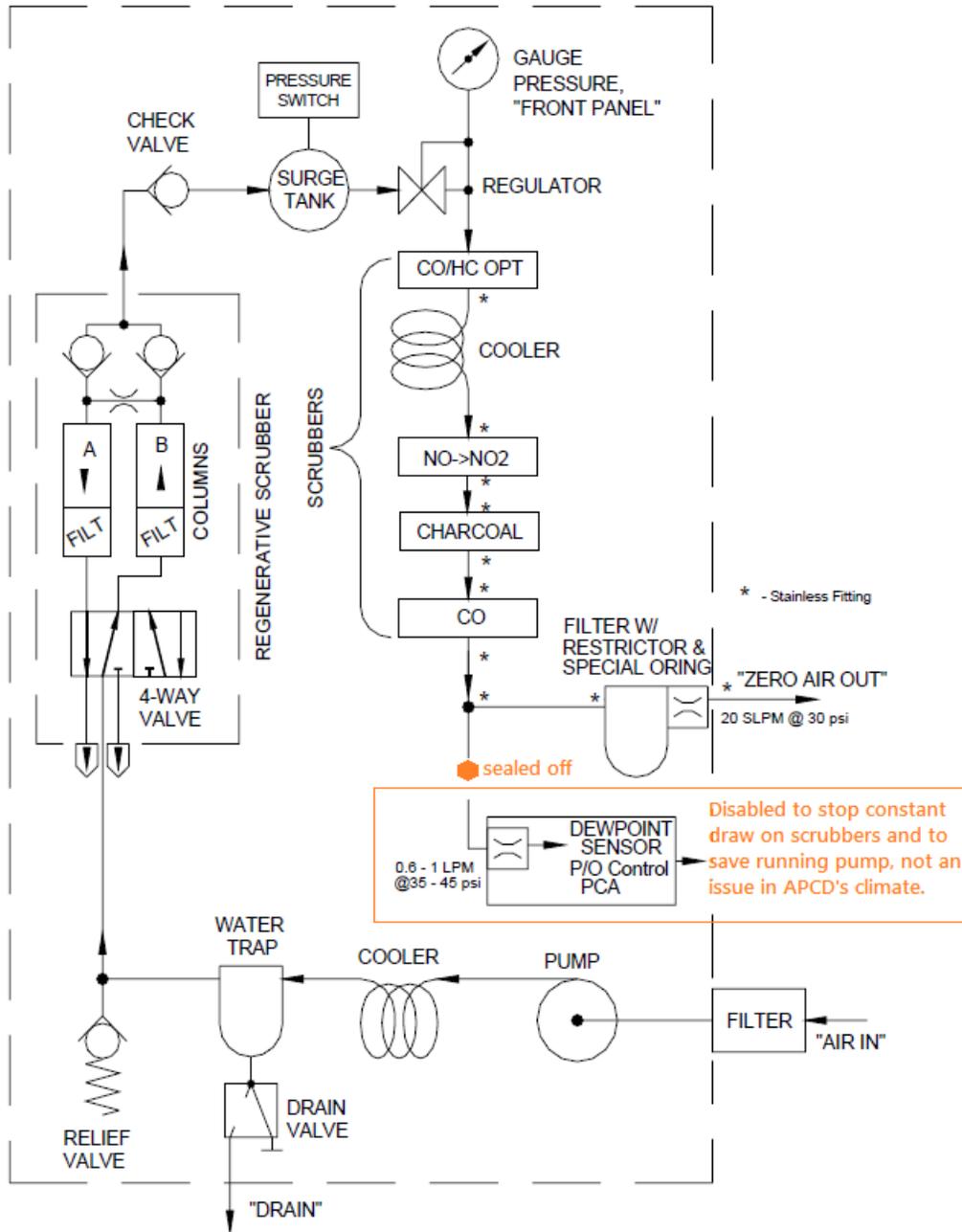


Figure 2. Typical zero-air supply system - TAP 701H

FLOW MEASUREMENT

STATION _____ DATE _____
 CALIBRATOR _____ ZERO AIR _____ VAC = _____ " PSI = _____ "
 CATALYTIC OXIDIZER at _____ mv/ _____ F/C
 GAS REGULATOR
 STANDARD CYL # _____ PRESS = _____ / _____ CONC = _____

| CAL SETTING | RAW FLOW MEASURED | AVG FLOW | TEMP °C | (BP-Pv) * 298.2 / (29.92 * (273.1 T)) | FLOW CONC @STP (Fd + Fg) | * Fg PPM OUT |
|-------------|-------------------|-------------|-------------|---|--------------------------|--------------|
| | | $\bar{X} =$ | $\bar{X} =$ | $(\frac{\quad}{\quad}) * \frac{298.2}{29.92 * (273.2 + \quad)}$ CF = | | |
| | | $\bar{X} =$ | $\bar{X} =$ | $(\frac{\quad}{\quad}) * \frac{298.2}{29.92 * (273.2 + \quad)}$ CF = | | |
| | | $\bar{X} =$ | $\bar{X} =$ | $(\frac{\quad}{\quad}) * \frac{298.2}{29.92 * (273.2 + \quad)}$ CF = | | |
| | | $\bar{X} =$ | $\bar{X} =$ | $(\frac{\quad}{\quad}) * \frac{298.2}{29.92 * (273.2 + \quad)}$ CF = | | |
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| | | $\bar{X} =$ | $\bar{X} =$ | $(\frac{\quad}{\quad}) * \frac{298.2}{29.92 * (273.2 + \quad)}$ CF = | | |
| | | $\bar{X} =$ | $\bar{X} =$ | $(\frac{\quad}{\quad}) * \frac{298.2}{29.92 * (273.2 + \quad)}$ CF = | | |

CALIBRATOR FLOW Rotometer _____ Total _____ Excess _____ FLOW STANDARD = Make and SN # _____ or HBM - 1 # _____ mb

- BP = Barometric Pressure "Hg
- STP = 25° C & 29.92 "Hg
- Fd = Flow rate of dilution air
- Fg = Flow rate of gas standard
- Pv = Vapor
- T = Temperature
- CF = Correction Factor (dimensionless) to compensate flow for temp/barometric pressure

COMMENTS

Figure 3 (continued)



COLORADO DEPARTMENT OF PUBLIC HEALTH AND ENVIRONMENT

Air Pollution Control Division - Technical Services Program
 Ozone, Carbon Monoxide, Sulfur Dioxide Calibration Form



| | | | | | | | | | | | | | |
|---|-----------------|---------------|-----------------|---------------------------------|--------------------|---|--------------|-----------------------------------|-----------|-----------------|------------|--------------------|-----------------|
| Site Name: _____ | | | | | | | | | | | | | |
| Site Info. | | | | Date Time | | | | Calibration Equipment Info | | | | | |
| AQS ID: _____ | | | | Date (mm/dd/yy) _____ | | | | Calibrator Type: _____ | | | | | |
| Parameter: _____ | | | | Time (hh:mm) _____ | | | | Calibrator SN: _____ | | | | | |
| Analyzer Type: _____ | | | | Prev Cal. Date (mm/dd/yy) _____ | | | | Calibrator Cert Date: _____ | | | | | |
| Analyzer SN: _____ | | | | Calibrator's Initials: _____ | | | | Cert. Slope (m): 1.00000 | | | | | |
| Site Precision Source Info. | | | | | | | | Cert. Intercept (b): 0.00000 | | | | | |
| Source Type: _____ | | | | | | | | Calibration Gas Info. | | | | | |
| Source SN: _____ | | | | | | | | Bottle SN: _____ | | | | | |
| Conc.: _____ | | | | | | | | Conc.: _____ | | | | | |
| Exp. Date: _____ | | | | | | | | Exp. Date: _____ | | | | | |
| Pre-Calibration System ZSP Evaluation | | | | | | Post-Calibration System ZSP Evaluation | | | | | | | |
| Pre-Calibration Analyzer Slope: _____ | | | | | | Post-Calibration Analyzer Slope: _____ | | | | | | | |
| Pre-Calibration Analyzer Intercept: _____ | | | | | | Post-Calibration Analyzer Intercept: _____ | | | | | | | |
| Set Point | Source Conc. | Display Conc. | DAS Conc. | Display % Diff | DAS % Diff | Set Point | Source Conc. | Display Conc. | DAS Conc. | Display % Diff | DAS % Diff | | |
| Zero | | | | | | Zero | | | | | | | |
| Span | | | | | | Span | | | | | | | |
| Precision | | | | | | Precision | | | | | | | |
| Pre-Calibration Points | | | | | | Post-Calibration Points | | | | | | | |
| Set Point | Conc. Out Conc. | DAS Conc. | Conc. Adj Conc. | DAS % Diff | Best Fit DAS Conc. | Best Fit (% RE) | Set Point | Conc. Out Conc. | DAS Conc. | Conc. Adj Conc. | DAS % Diff | Best Fit DAS Conc. | Best Fit (% RE) |
| Zero | | | | | | | Zero | | | | | | |
| Level 1 | | | | | | | Level 1 | | | | | | |
| Level 2 | | | | | | | Level 2 | | | | | | |
| Level 3 | | | | | | | Level 3 | | | | | | |
| Level 4 | | | | | | | Level 4 | | | | | | |
| Level 5 | | | | | | | Level 5 | | | | | | |
| Level 6 | | | | | | | Level 6 | | | | | | |
| Level 7 | | | | | | | Level 7 | | | | | | |
| Pre - Regression Results | | | | | | Post - Regression Results | | | | | | | |
| Slope: _____ | | | | | | Slope: _____ | | | | | | | |
| Intercept: _____ | | | | | | Intercept: _____ | | | | | | | |
| R2: _____ | | | | | | R2: _____ | | | | | | | |
| Comments: <div style="background-color: #e0ffe0; height: 100px; border: 1px solid black;"></div> | | | | | | | | | | | | | |

Figure 4. Calibration Report

MAINTENANCE REPORT

DATE _____
STATION _____
ASSIGNED TO _____
ORIGINATED BY _____
ANALYZER or EQUIPMENT _____ S/N _____

MALFUNCTION DESCRIPTION OR COMPLAINT

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ACTION TAKEN

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DATA TO BE DELETED (IF ANY) ENTER EXACT DATES AND DATA HOURS

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| |

COMPLETED BY _____
COMPLETION DATE _____

Figure 7. Maintenance Report Form